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INSTRUCTION MANUAL

KEPCO®

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MODULAR
design group

Model PAR-4 (C)

Serial No. *P80762...*

INSTRUCTION MANUAL

The KEPCO equipment described in this instruction manual is of proprietary design, covered by one or more of the following United States patents and/or by other (U.S. and Foreign) Patents or patents pending.

2,992,379	3,112,439	3,241,042	3,275,948
2,992,386	3,128,423	3,243,690	3,303,411
3,028,538	3,131,344	3,243,749	3,303,412
3,056,905	3,210,619	3,275,925	3,303,415
3,088,053	3,226,628	3,275,927	3,305,763
3,092,757	3,241,054		

Canadian Patents: 733629 — 736084

Australian Patents: 263,835 — 264,975

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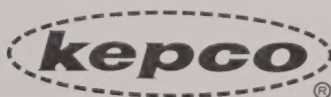


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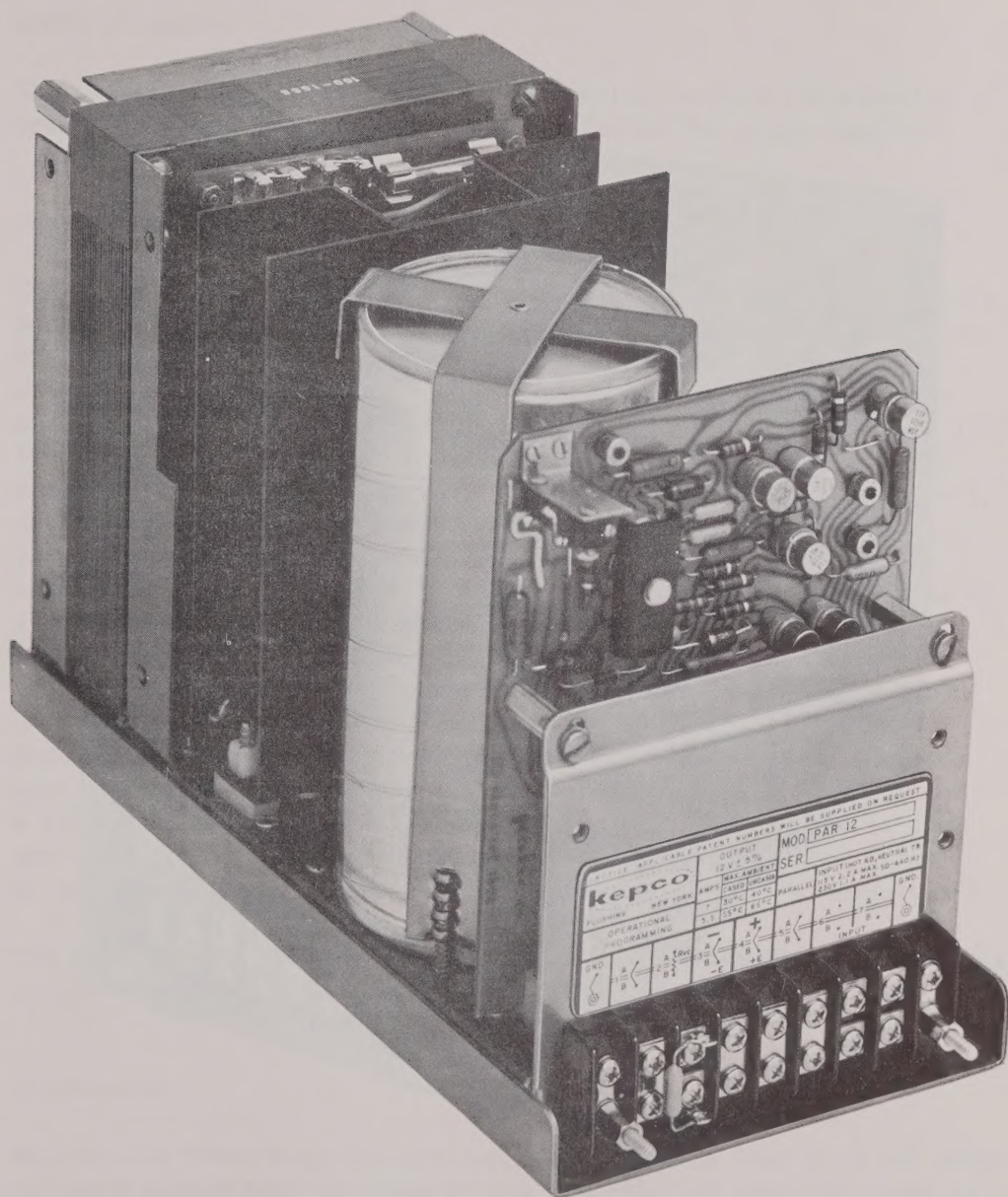


FIG. 1-1 PAR POWER SUPPLY MODULE, UNCASSED

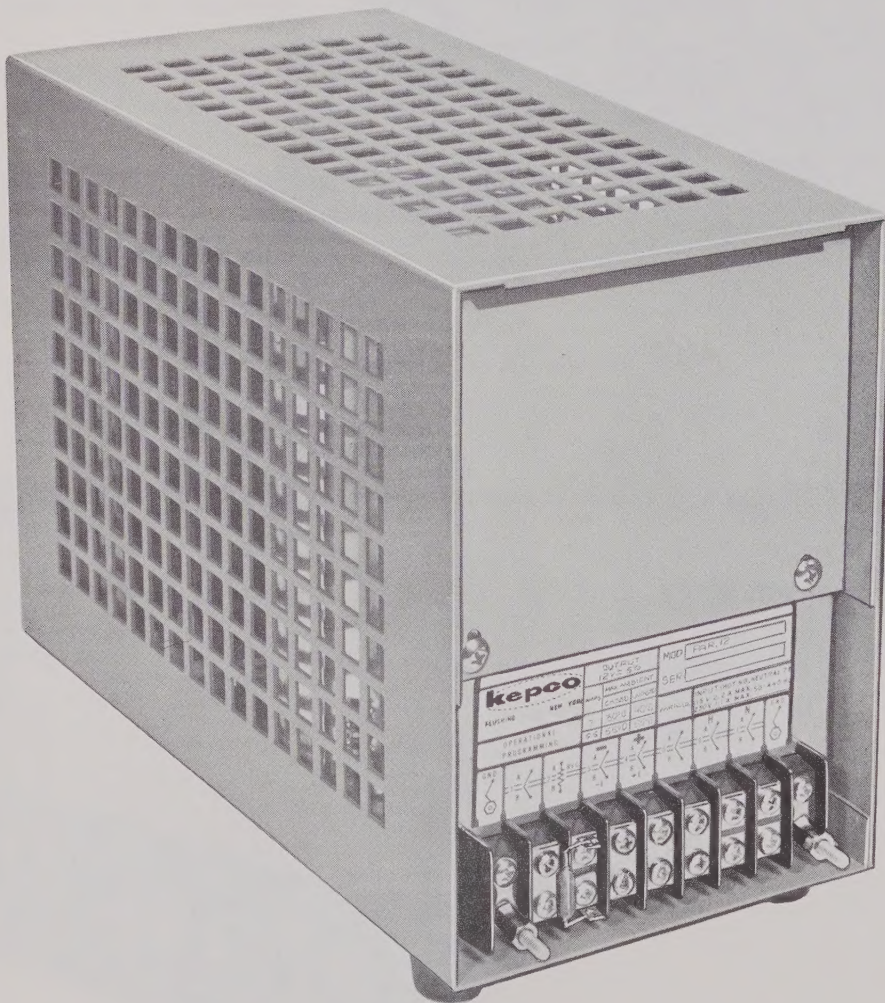


FIG. 1-2 PAR POWER SUPPLY MODULE, CASED

SECTION I - INTRODUCTION

1-1 SCOPE OF MANUAL

1-2 This instruction manual contains information for the installation, operation and maintenance of the Kepco Series PAR Power Supplies.

1-3 GENERAL DESCRIPTION (Refer to FIG. 1-1)

1-4 The Kepco PAR design group consists of line and load regulated power supply modules incorporating a feedback regulating system utilizing the Kepco Comparison Bridge Regulator. The specifications and electrical characteristics of these units are identical, with the exception of output range and output impedance. (Refer to Table 1-1) The PAR power supplies are modular units, intended to be operated either as fixed voltage sources ($\pm 5\%$ output voltage vernier control, self contained), or they may be programmed, with linear derating using external controls. An overload protection circuit, with a negative resistance characteristic for current limiting, provides an exceptional degree of safety for any applied load. The PAR power supplies are multi-rated for increased output current delivery at reduced ambient operating temperatures. (Refer to paragraph 3-1)

1-5 Modular construction of the Series PAR power supplies permits their use either as a bench supply or in systems applications as part of a larger installation. All external dimensions in the PAR series are identical. Mounting choices include chassis mounting, bench or rack panel installation. (Refer to paragraph 1-7 "Accessories")

1-6 The main chassis and supporting frame of the Series PAR Power Supplies is constructed of cold-rolled, cadmium plated steel.

1-7 ACCESSORIES

1-8 PAR Modular Power Supplies are supplied without a line cord and plug. AC input connections are made on the rear-barrier strip as shown in FIG. 2-1.

1-9 The following accessories are available from KEPCO on special order:

- a) Case. Wrap-around cover with end plate and four (removable) feet for bench use. (Model CA-200) (Refer to FIG. 1-2)

b) Rack Adaptor:

- 1) Model RA 8-2 (5 $\frac{1}{4}$ " high x 19" wide) accomodates 2 PAR Modules.
- 2) Model RA 9-3 (7" high x 19" wide) accomodates 3 PAR Modules.
- 3) Model RA 25-1 (5 $\frac{1}{4}$ " high x 19" wide) accomodates one PAR Module.

c) Over-Voltage Protector, Model VP-PAR refer to Kepco Main Catalog or inquire directly: Kepco Inc., 131-38 Sanford Avenue, Flushing, N.Y. 11352.

1-10 SPECIFICATIONS, GENERAL

- a) Input Requirements: 105 to 125 V AC or 210 to 250 V AC, 50 to 440 Hz, single phase.
Input current approximately 2 amperes, 200 watts.
- b) Ambient Operating Temperature:
 - 1) Uncased: -20°C to +65°C maximum (Refer to Table 1-1)
 - 2) Cased: -20°C to +55°C maximum (Refer to Table 1-1)
- c) Storage Temperature: -40°C to +85°C
- d) Isolation Voltage: A maximum of 500 volts can be connected between the chassis and either output terminal.

1-11 SPECIFICATIONS, PERFORMANCE

- a) Internal Controls: PAR power supplies are equipped with four (4) internal controls:
 - 1) "E_O max. Adj." (R25) used as a vernier control to adjust the control current (I_b) and effectively the output voltage within $\pm 5\%$. Factory adjusted to deliver the maximum rated output voltage in conjunction with the 1% fixed voltage control resistor, installed across barrier strip terminals (2a)-(2b).
 - 2) "I_O max. Adj." (R4, or R204 in Models PAR-4 and PAR-7: Current limit control, factory adjusted for maximum rated output current at the ambient temperatures shown in Table 1-1, but re-adjustable for current limiting in the range from 5 to 105% of the output current, and for increased current output at lower ambient operating temperature. (Refer to paragraph 3-1)

3,4) LAG NETWORK ADJUSTMENTS: Provided for stabilizing the amplifier of the SERIES PAR power supplies after component replacement. These adjustments are set at the factory for optimum performance and need no re-adjustment under ordinary circumstances. For the description of lag network alignment after repair or component replacement see paragraph 5-9.

h) External Controls:

- 1) A fixed 1% low temperature coefficient resistor (R201) is installed between barrier strip terminals (2a)-(2b) acting as the voltage control resistor and providing (in conjunction with the "E_o max. Adj." control) for maximum rated output voltage.
- 2) Resistor programming can be performed by replacing the provided resistor with a rheostat or decade box. (Refer to Section III)
- 3) Other programming terminals are provided at the barrier strip for programming either resistively or with external voltages. (Refer to Section III)

c) Overload Protection: PAR power supplies have an over current characteristic resembling that of a negative resistance. (Refer to FIG. 3-3) When overloaded, the output current is automatically reduced along the adjustable cut-off locus. The negative resistance characteristic may cause non-linear loads (requiring large starting surge currents) to "lock out". For such loads, series starting resistors must be used to keep the surge current within the operating area of the Model PAR Power Supply.

d) Remote Error Sensing: Error sensing terminals at the barrier strip permit specified regulation to be maintained directly across the load by compensating for voltage drops up to 0.5 volts across each load connecting wire. (Refer to Section III)

e) Series and Parallel Operation: Terminals at the barrier strip provide for series connection of PAR modules and parallel operation in the master-slave configuration. (Refer to Section III)

f) Cooling: Heat removal is by convection cooling. Sufficient space must be provided to allow for proper circulation around the unit. If the power supply is to be rack-mounted or installed into confined spaces, care must be taken not to exceed the ambient temperature specifications as given in Table 1-1 of this manual.

g) Overshoot: No output voltage overshoot from turn-on, turn-off or power failure for output settings above 25% of maximum rated

- g) Overshoot: No output voltage overshoot from turn-on, turn-off or power failure for output settings above 25% of maximum rated voltage. Below 25%, output overshoot is a function of load and is negligible for output currents greater than 10% of the maximum rated value.

1-12 SPECIFICATIONS, VOLTAGE REGULATION MODE (Specifications apply only if either the supplied external voltage control resistor, or an equivalent component with a temperature coefficient of 100 parts per million or better is used.)

a) Regulation:

- 1) Line: Less than 0.005% output voltage change for AC line input changes from 105 to 125 V AC or from 210 to 250 V AC.
- 2) Load: Less than 0.01% or 0.5 mV output voltage change, whichever is greater, for output current changes from "no load" to the current limit locus. (Refer to FIG. 3-2)

- b) Stability: Output voltage varies less than 0.02% or 2 mV, whichever is greater, over a period of 8 hours after warm-up. Measured at constant line voltage, load and ambient temperature.

- c) Temperature Coefficient: Output voltage changes less than 0.02% per °C.

- d) Ripple: Less than 0.25 mV, (rms).

- e) Recovery Time: 50 microseconds.

- f) Output Impedance: Specified for each model within the load frequency range shown in Table 1-1. Above 1 kHz, include the reactive impedance of the effective series inductance as indicated.

1-13 SPECIFICATIONS, CURRENT REGULATION MODE, EXTERNAL SENSING (Specifications apply only if the external current sensing resistor and control resistor have a temperature coefficient of 20 parts per million, or better)

- a) Output Range: Current regulation from approximately 1 mA to 100% of the maximum rated output current, within the current limit locus.
- b) Compliance: (Refer to FIG. 3-3) Compliance voltage is from the intercept on the I_{limit} locus at the operating current selected,

vertically up to 105% line of the maximum output voltage. For variable current output, two vertical lines are drawn upwards from the selected current limits on the I_{limit} locus to the 105% line of the maximum output voltage. The compliance voltage range is then within the surface bordered vertically by the selected operating limits and horizontally by the maximum output voltage (105% line) and the I_{limit} locus. The compliance voltage varies automatically through this region as required to regulate the output current into a varying load. For loads requiring compliance voltages outside of the established operating region, automatic bounding takes place due to the characteristic of the cut-off locus.

c) Regulation:

- 1) Line: Less than 0.005% output current change for AC line input changes from 105 to 125 V AC or from 210 to 250 V AC if a minimum sample voltage of 1 volt is maintained across the external sensing resistor.
- 2) Load: Less than 0.01% output current change for the maximum change in load resistance within the rated compliance range. A minimum sample voltage of 1 volt must be maintained across the external sensing resistor.
- d) Stability: Output Current varies less than 0.02% or 1 mA, whichever is greater, over a period of 8 hours after warm-up. Measured at constant line voltage, load and ambient temperature.
- e) Temperature Coefficient: Output current changes less than 0.02% per °C, plus the T.C. of the external resistors used.

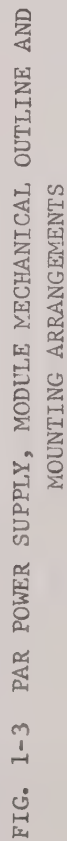
1-14 SPECIFICATIONS, PHYSICAL (Refer to FIG. 1-3)

- a) Terminations: Barrier strip screw type terminals provide for AC power line input, DC output, error sensing and programming terminals as well as auxiliary terminals for the connection of an over voltage protective device.
- b) Dimensions:
 - 1) Uncased : 6 3/4" H x 4 3/4" W x 10 3/8" D.
 - 2) Cased : 6 15/16" H x 5" W x 10 7/16" D.
- c) Standard Finish:
 - 1) Chassis: Cadmium plated, cronak wash.
 - 2) Case: Blue epoxy finish.

MODEL	OUTPUT [†] VOLTS	OUTPUT CURRENT at ambient temp		OUTPUT IMPEDANCE		
		65°C ▼ 55°C ▼▼	40°C ▼ 30°C ▼▼	Ohms DC to 100 cps	Microhenries 100 cps to 1 kc	1 kc to 100 kc + μ h
PAR-4	4 $\pm$ 5%	0-9.0	0-11.0	0.0001	0.005	0.1 + 0.5
PAR-7	7 $\pm$ 5%	0-8.0	0-10.0	0.0001	0.005	0.1 + 0.5
PAR-12	12 $\pm$ 5%	0-5.5	0-7.0	0.0002	0.005	0.1 + 0.5
PAR-15	15 $\pm$ 5%	0-4.6	0-6.0	0.0003	0.005	0.1 + 0.5
PAR-24	24 $\pm$ 5%	0-3.4	0-4.0	0.0006	0.005	0.1 + 0.5
PAR-28	28 $\pm$ 5%	0-3.1	0-3.7	0.0008	0.005	0.1 + 0.5
PAR-36	36 $\pm$ 5%	0-2.3	0-2.8	0.0015	0.005	0.1 + 0.5
PAR-48	48 $\pm$ 5%	0-1.8	0-2.3	0.0022	0.005	0.1 + 0.5
PAR-60	60 $\pm$ 5%	0-1.5	0-2.0	0.003	0.005	0.1 + 0.5

▼ Uncased: ▼▼ Cased

TABLE 1-1 OUTPUT RANGES AND MAXIMUM IMPEDANCE,
PAR POWER SUPPLY MODULES



SECTION II - INSTALLATION

2-1 UNPACKING AND INSPECTION

2-2 This power supply has been inspected and tested at the factory prior to packing and it is shipped ready for operation. After careful unpacking, inspect the instrument for shipping damage before attempting to operate it. Perform the operational check as described in Par. 2-11 below. If there is any indication of damage, file a claim immediately with the responsible transport service.

2-3 TERMINATIONS (Refer to FIG. 2-1)

2-4 All input and output connections are made on the barrier strip as shown in FIG. 2-1. The power supply is shipped with voltage control resistor R201 placed across terminals 2A and 2B and will deliver nominal output voltage with this component in place.

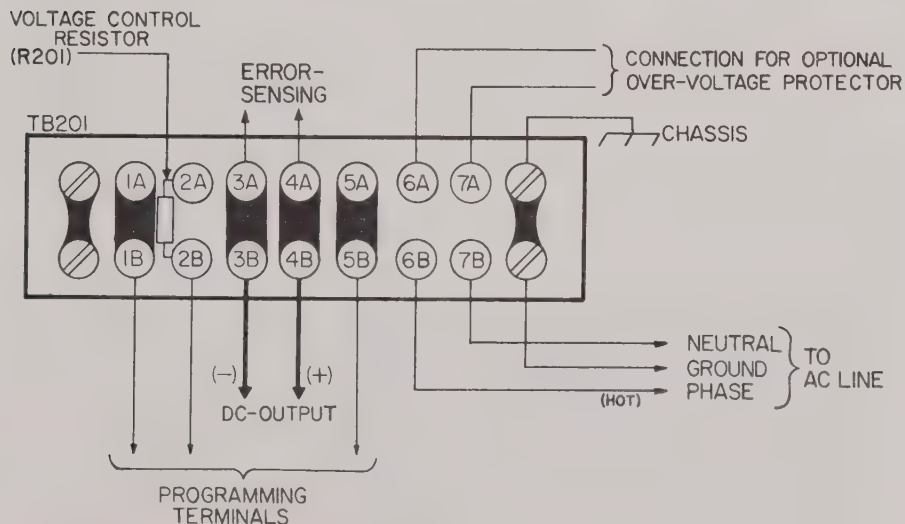
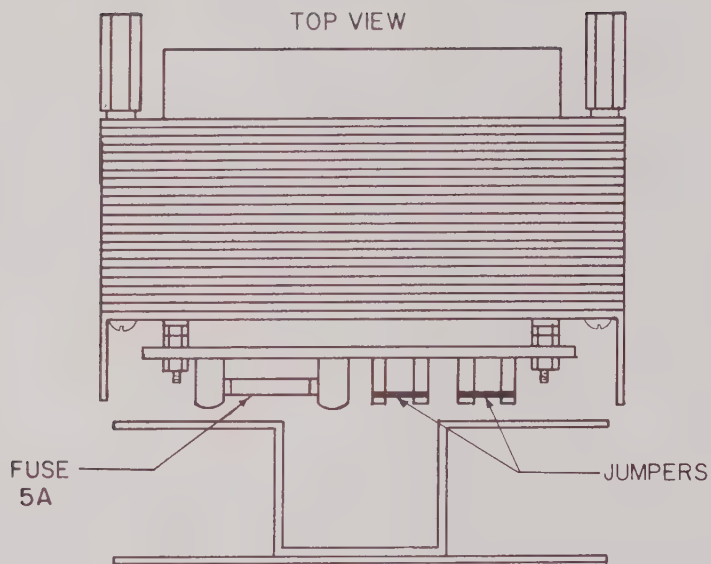


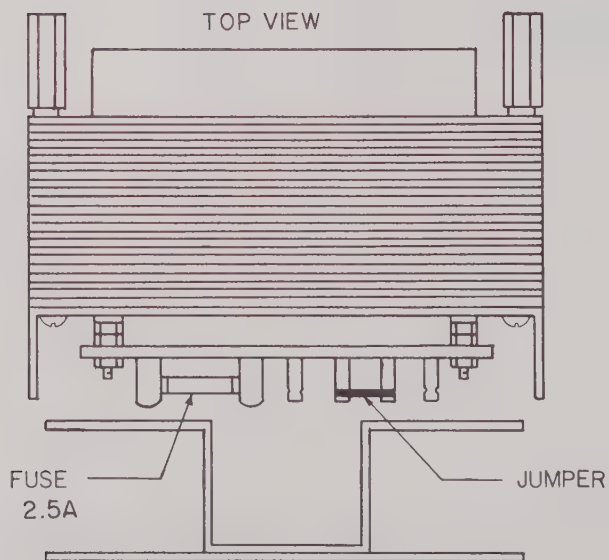
FIG. 2-1 TERMINATIONS, PAR DESIGN GROUP

2-5 AC POWER REQUIREMENTS

2-6 Standard models of the PAR Group are shipped for operation on a single phase, 50 to 440 Hz line, 105 to 125 V AC. They may be readily converted to 210 to 250 V AC operation by re-wiring the jumpers on the main transformer terminal board and reducing the fuse value to one half the value used for 105 to 125 V AC operation. (Refer to FIG. 2-2)



A) 105 TO 125VAC OPERATION



B) 210 TO 250 VAC OPERATION

FIG. 2-2 STANDARD JUMPER CONNECTIONS FOR 105-125 V AC OPERATION (A)
AND CONNECTIONS FOR 210-250 V AC OPERATION (B)

2-7 GROUNDING

- 2-8 For safety reasons it is imperative that the metal chassis of the power supply be kept at ground potential. If a three wire safety line cord and plug are used and connected to a properly grounded outlet, grounding is automatically accomplished with the third wire of the line cord connected to one of the grounding terminals. (Refer to FIG. 2-1) If a line cord with only two wires is used however, the chassis of the PAR power supply must be returned to AC ground through a separate wire.

2-9 ISOLATION

- 2-10 The DC output terminals of the PAR power supply are isolated from chassis and from the AC power line except for a capacitive connection from the negative output terminal to chassis. Since no DC connection to the chassis exists, either side of the supply may be grounded, or a maximum of 500 volts (DC or p-p) may be connected between chassis and either output terminal.

2-11 OPERATIONAL CHECK

- 2-12 An operational check for the purpose of preliminary inspection after unpacking may be performed as follows:

a) Equipment Required:

- 1) Three wire safety line cord and plug.
- 2) Voltmeter with range covering the maximum output voltage of the model under test. Accuracy of the meter as desired.

b) Connect components as shown in FIG. 2-3.

c) Connect unit to power line and measure output voltage across M-1.

- 2-13 For fixed voltage applications, the output voltage may be calibrated to any point within $\pm 5\%$ of the output voltage of the supply by adjusting R25, until M-1 shows the desired output voltage. The accuracy of the reading will of course be determined by the voltmeter used. Adjustments for other than the maximum output voltages are covered in Section III paragraph 3-14: "Resistance Programming".

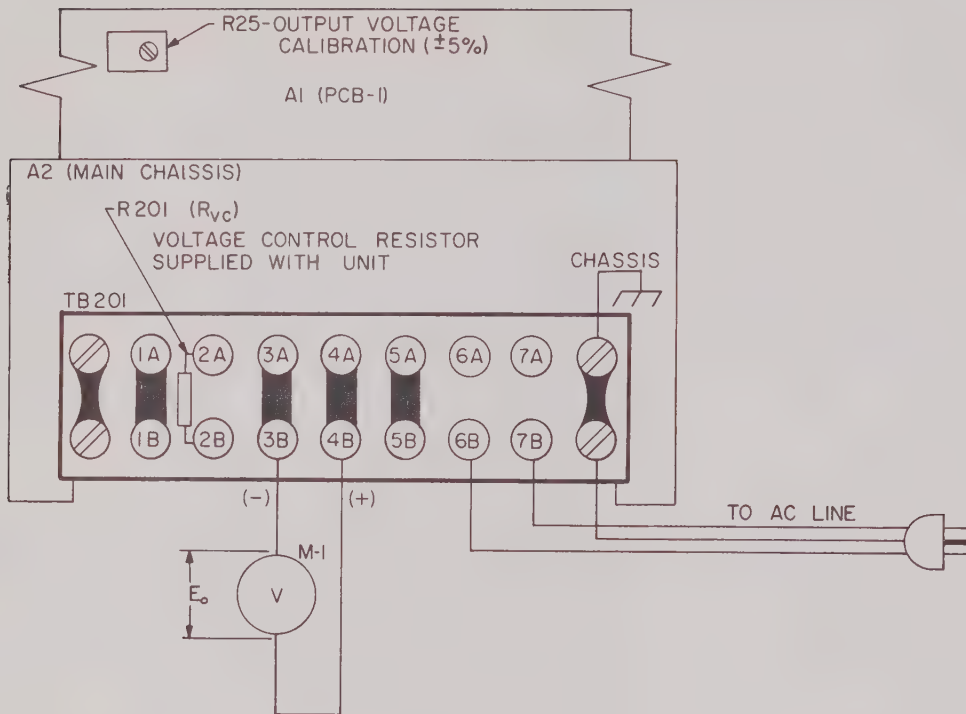


FIG. 2-3 PAR POWER SUPPLY GROUP, OPERATIONAL CHECK

2-14 INSTALLATION

2-15 The PAR power supply may be installed in any position and is designed for a variety of mounting methods. It may be used as a bench supply or, as part of a larger system, mounted directly into the installation. Rack-panel mounting is available without alterations to the chassis of the unit. (Refer to Paragraph 1-7, "Accessories")

2-16 Precautions must be taken if the PAR power supply is either rack-mounted or installed as part of a larger system. Adequate spacing around the unit must be allowed for sufficient air flow. If congested mounting can not be avoided, the ambient temperature must not be allowed to rise beyond the specifications of the supply. If necessary, forced air cooling in the mounting environment must be used.

CAUTION: The negative resistance character of the cut-off locus may cause severely non-linear loads (requiring large starting surge currents) to "lock out" for certain settings of the cut-off current limit. For such loads, a series starting resistance can be used to limit the starting surge so that operation can be contained within the shaded region of the graph. Some examples of non-linear loads are: high intensity filament lamps and motors.

SECTION III - OPERATING PROCEDURES

3-1 MULTI CURRENT RATING OF PAR POWER SUPPLIES.

3-2 The output current of the PAR Power Supply Group is specified as a function of ambient operating temperature as seen in Table 1-1. Two output current ratings for two ambient operating conditions are given for the cased, as well as the uncased models. Linear interpolation between the specified limits is permissible.

3-3 The current limit (I_{limit}) of the PAR power supply is factory set for the highest allowable operating temperature (lower current). If this output current is sufficient for the application intended, no resetting of I_{limit} is required and the power supply may be operated up to the high temperature limit. If the additional output current is required however, the current limit control (I_{limit}) may be reset, provided the specified lower ambient temperature is not exceeded. Proceed as follows:

- a) Set up the PAR power supply with variable resistor load and locate the CURRENT LIMIT ADJUSTMENT (Refer to FIG. 5-2) Turn this control fully clockwise.
- b) Turn supply "on" and adjust load until the desired output current is drawn. Monitor output voltage with an oscilloscope, having a vertical sensitivity of at least 100 $\mu\text{V}/\text{cm}$.
- c) Turn CURRENT LIMIT ADJUSTMENT counter clockwise until the output ripple increases substantially. Back off on the adjustment until the output ripple appears normal again.

CAUTION: DO NOT SHORT-CIRCUIT SUPPLY WHILE THE CURRENT LIMIT ADJUSTMENT IS SET AT ITS MAXIMUM POSITION.

- d) Install the power supply into its designated environment and measure the ambient temperature in the immediate vicinity of the (loaded) power supply. Refer to Table 1-1 to determine if the supply can be safely operated under the established conditions.

3-4 The following example should illustrate the use of the multi-ratings and the linear interpolation between them:

A Kepco Model PAR-36 (UNCASED) is to be operated with a load current of 2.5A. The ambient temperature measured, after actual operating conditions have been established, is 50°C. Is it safe to operate the supply under these conditions?

- a) From the information in the table of specifications (Table 1-1) a simple derating curve is constructed as follows:

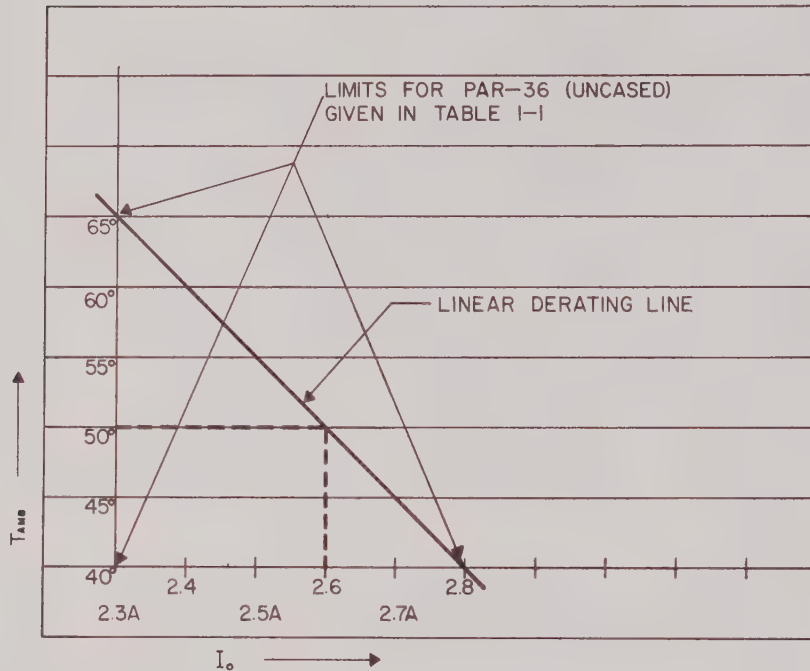


FIG. 3-1 CONSTRUCTION OF DERATING GRAPH

- b) The limits given in Table 1-1 are plotted to any convenient scale and then connected with a straight line (derating line). As seen immediately, at 50°C ambient operating temperature, the desired output current may be drawn safely.

3-5 STANDARD OPERATION (FIXED OUTPUT VOLTAGE)

- 3-6 With the supplied voltage control resistor (R201) in place across terminals (2A)-(2B), the power supply is ready for operation at the maximum rated output voltage, and maximum rated output current* may be drawn by the load. (Refer to Table 1-1 for specifications)
- 3-7 If lower, (fixed) output voltages are desired the voltage control resistor must be changed to a value proportional to the desired output voltage. For each volt of output, 1000 ohms of control resistance must be placed between terminals (2A)-(2B). Specifications of this power supply are only valid if the external control resistor is a metal-film or wire-wound unit with an accuracy of $\pm 1\%$ and a temperature coefficient of 100 parts per million or better. The output voltage may now be precision adjusted with the built-in voltage control vernier (R25, E_O MAX. ADJ., See FIG. 2-2 for location) Operation at lower output voltage requires consultation of the OPERATING CHARACTERISTIC GRAPH. (FIG. 3-3). Operation with continuous control of output voltage (programming) is discussed in the following paragraphs. Current limiting at other than the factory adjusted limit (105% of max. rated output current) is possible in the range from approximately 5% to 105% of maximum rated output current. The adjustment procedure for I_{limit} is described in paragraph 5-6.

3-8 INTRODUCTION TO PROGRAMMING

- 3-9 The purpose of this paragraph is to introduce the user of this equipment to the terminology and the basic relationships pertaining to the operation of the PAR Power Supply. These relationships become most important in applications involving special operating procedures.
- 3-10 The PAR power supply, utilizing the Kepco Comparison Bridge circuit, lends itself readily to output control by external means.
- 3-11 (Refer to FIG. 3-1 and FIG. 4-1) The operating equations of the Kepco bridge at balance ($V_{AA'} = 0$) are:

$$\frac{E_O}{E_R} = \frac{R_{VC}}{R_R} \quad (1) \quad \frac{E_R}{R_R} = I_b \quad (2) \quad E_O = I_b R_{VC} \quad (3)$$

*"Maximum rated OUTPUT current" in the PAR Design Group is a function of ambient operating temperature. Refer to paragraph 3-1.

Where E_O = Output Voltage;
 E_R = Reference Voltage;
 R_R = Reference Resistor;

R_{VC} = Control Resistance;
 I_b = Bridge Current

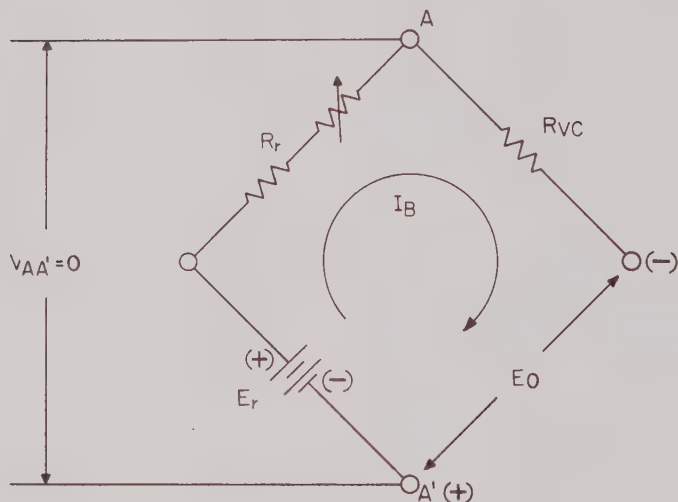


FIG. 3-2 KEPCO COMPARISON BRIDGE, SIMPLIFIED

3-12 As seen from equation (1), the output voltage (E_O) of the PAR Power Supply may be influenced by changing any one of the three other quantities. Rewriting equation (1), we have:
$$E_O = \frac{E_R}{R_R} \times R_{VC}$$

The ratio E_R/R_R constitutes the bridge current I_b , (Eq. 2) We can therefore write: $E_O = I_b R_{VC}$ (Eq. 3). Making I_b a precision quantity (Bridge current adjustment is described in par. 3-15) establishes a precision programming ratio, so that the accuracy of E_O depends solely on R_{VC} . Since I_b is a nominal 1 mA in the PAR power supply, referring to (Eq. 2), it is seen that 1000 Ω of control resistance (R_{VC}) is needed for each volt of output. This establishes a programming ratio of 1000 ohms per volt. This method of output voltage control is referred to as resistance programming.

3-13 Rewriting equation (1), $E_R \times \frac{R_{VC}}{R_R} = E_O$, keeping the gain ratio

R_{VC}/R_R fixed and varying E_R , will change the output voltage proportional to the change in E_R . (Voltage Programming).

3-14 Power Supply programming is possible in a great variety of methods; some of which are described in the following paragraphs. For a more detailed treatment, please refer to the Kepco "Power Supply Handbook", available from your Kepco Representative or write directly to "Kepco Inc., 131-38 Sanford Ave., Flushing N.Y. 11352".

CAUTIONS: a) Before programming by any method or in any mode, check the over load characteristics of your PAR power supply (FIG. 3-3). Derating takes place automatically along the output current cut-off locus. Do not attempt to adjust I_{limit} beyond its maximum factory adjusted setting. Follow the adjustment procedure given in paragraph 5-6 if this control must be adjusted. Settings of this control beyond the maximum current capability of the supply (possible because of component tolerances) will result in pass-element failure.

b) All programming resistors and adjustment components externally connected to the power supply must be high quality wire-wound or metal-film resistors with sufficient wattage and with temperature coefficients better than 100 parts per million.

3-15 OPERATING CHARACTERISTIC GRAPH (Refer to FIG. 3-3)

3-16 If the power supply is at any time operated below its maximum output voltage the OPERATING CHARACTERISTIC GRAPH (FIG. 3-3) must be consulted. Maximum rated output current ($I_O \text{ max.}$)* can be drawn from 105% to 95% of maximum rated output voltage ($E_O \text{ max.}$) with the internal I_{limit} CONTROL set to maximum I_O . At 95% E_O the output current starts to limit automatically and derates linearly from this point to zero. (Line A). For example, at 50% E_O , the output current will limit at about 53% of its maximum rated value, at 20% E_O it will limit at about 22% I_O . The shaded area in the graph represents therefore the operating area of the power supply with the I_{limit} CONTROL set for maximum rated output current.

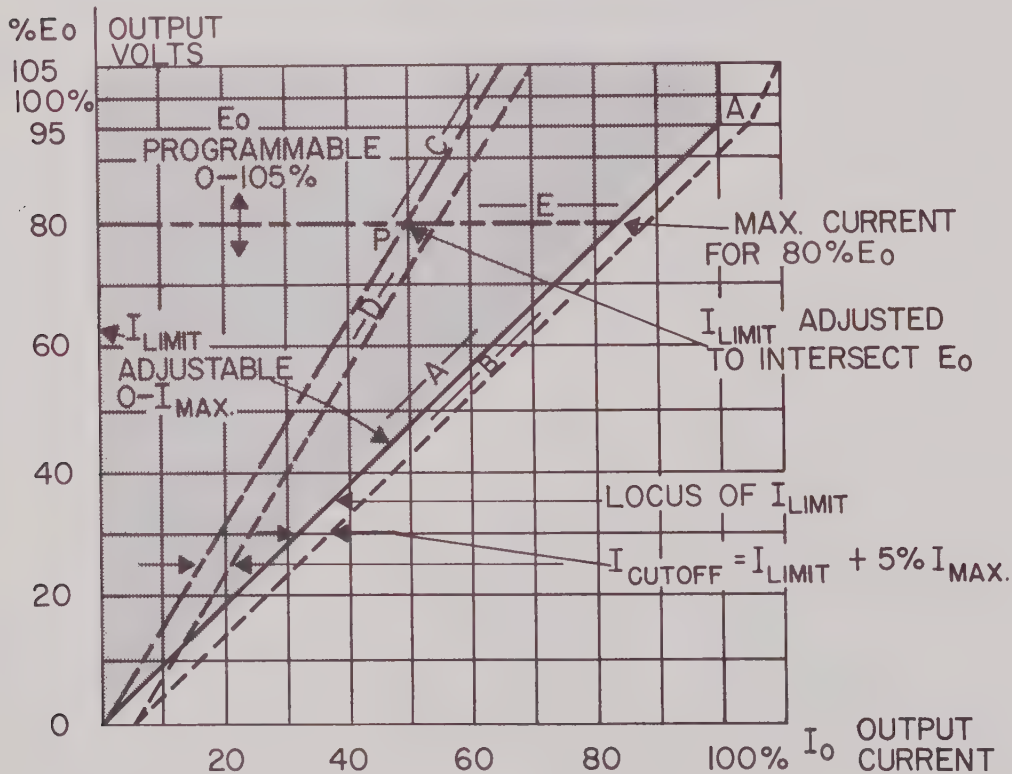
3-17 For applications requiring an I_{limit} CONTROL setting less than the factory adjusted maximum, a new operating area may be determined on the chart as follows:

a) Draw a horizontal line at the minimum desired operating voltage. (line E).

*Note: The "maximum rated output current" of the power supplies in the Par Design-Group is a function of ambient operating temperature. (Refer to par. 3-1)

- b) Select I_O limit (50% I_{MAX} .) and intersect line E at this point (Point P).
- c) Draw a line between point P and the origin (0,0). The area above line E and to the left of the resulting line (line C) is the new operating area, and the output current will now limit along line C.

Lines D and B, parallel to lines A and C represent the current cut-off for the supply. Current cut-off at any point equals I_{LIMIT} plus 5% I_O maximum. If a new I_{LIMIT} is adjusted therefore, the cut-off current (short circuit current) will be $I_{LIMIT} + 5\% I_O \text{ max.}$



NOTES: POINT "A" DETERMINED BY OPERATING TEMPERATURE
 LINES "B" AND "D" REPRESENT THE ACTUAL CUT-OFF
 LOCI OF THE SUPPLY. THE CUT-OFF CURRENT VALUE
 WILL BE 5% GREATER THAN THE ADJUSTED I_{LIMIT}
 AT ANY POINT.

FIG. 3-3 DERATING CHART, PAR DESIGN GROUP

3-18 RESISTANCE PROGRAMMING

- 3-19 Programming Ratio Adjustment. Resistance programming with precision decades or other highly accurate resistances, requires precise calibration of the bridge current (I_b) in order to achieve exact results. On the PAR power supplies an internal control is provided for convenient calibration of I_b . If a low impedance milliammeter is available, I_b may be adjusted directly by inserting the instrument in series with the voltage control resistor across terminals (2a)-(2b) and setting R25 (Refer to FIG. 2-2 for location) to precisely 1 mA. Another method is described below.

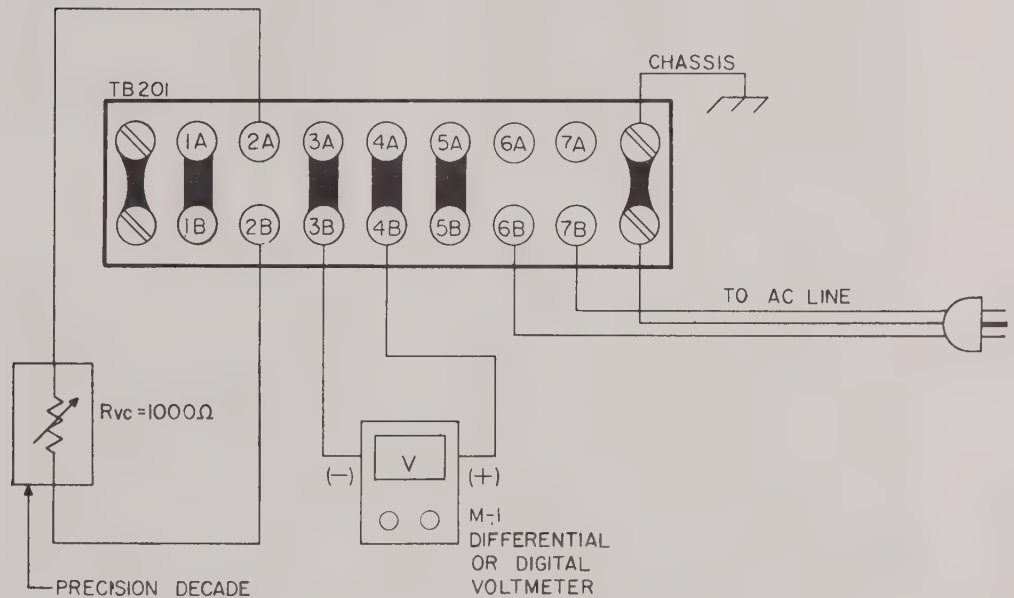


FIG. 3-4 ADJUSTMENT FOR EXACT PROGRAMMING RATIO

3-20 PROCEDURE

a) Equipment Required:

- 1) Differential or digital voltmeter (M1)
- 2) Programming resistor (Precision Decade) (R_{vc})

- b) Connect calibrating set-up as shown in FIG. 3-4 and set precision decade to 1000 ohms. (or use single, 1000 Ω precision resistor).

- c) Connect AC power. Adjust R25 so that precisely 1 volt is read out on M-1.
- d) Remove M-1. The exact programming ratio of 1000 ohms per volt is now established. For each 1000 ohms, one volt of output will result. Careful adjustment will yield programming linearities in the order of 0.05%.

3-21 VOLTAGE PROGRAMMING

- 3-22 The output voltage of the PAR power supply can be varied by means of another, external voltage source. This external, variable programming source takes the place of and functions as the internal reference voltage of the PAR supply. The output voltage "follows" the variable programming source and remains in a constant proportion to it. The relationship governing this type of programming is derived from equation (1) and can be expressed as:

$$E_o = E_i \left(\frac{R_{vc}}{R_c} \right),$$

Where: E_o = Output Voltage to be Programmed.
 E_i = Programming Voltage.
 R_{vc} = Voltage Control Resistance (internal or external as desired).
 R_c = External Coupling Resistor.

3-23 PROCEDURE

- 3-24 Since the concept of voltage programming is a very broad one and its applications are always subject to the particular requirements, only a simple example will be given here.
- a) Example: A PAR-24 is to be voltage programmed from zero to 24 volts by a programming source with the following specifications:
 - 1) Output unipolar, variable from zero to (-) 6 volts.
 - 2) Stability comparable to PAR power supply.
 - 3) Capable of delivering at least 1 mA current. (The Kepco FG-100 Function Generator for triangular wave shapes may serve as an example of a programming source).

While the programming source varies from zero to 6 volts, the output of the PAR power supply will vary from zero to 24 volts, resulting in a programming gain of four. The voltage control resistor (R_{vc}) for

24 volts is 24 K ohm. Substituting these values in our programming equation, we have:

$$E_o = E_i \frac{R_{vc}}{R_i}, \quad R_i = \frac{6 \text{ V } (24 \text{ K})}{24 \text{ V}} = 6 \text{ K}.$$

The control resistor R_i is therefore 6 K.

- b) Connect the selected components as shown in FIG. 3-5.
- c) Turn power supply "on" and programming source "on".
- d) With the programming source at precisely 6 V, adjust R25 on the power supply to exactly 24 volts output voltage.
- e) Varying the programming source in any manner (within the available programming speed of the PAR power supply) will cause the output voltage of the power supply to follow at the established gain ratio.

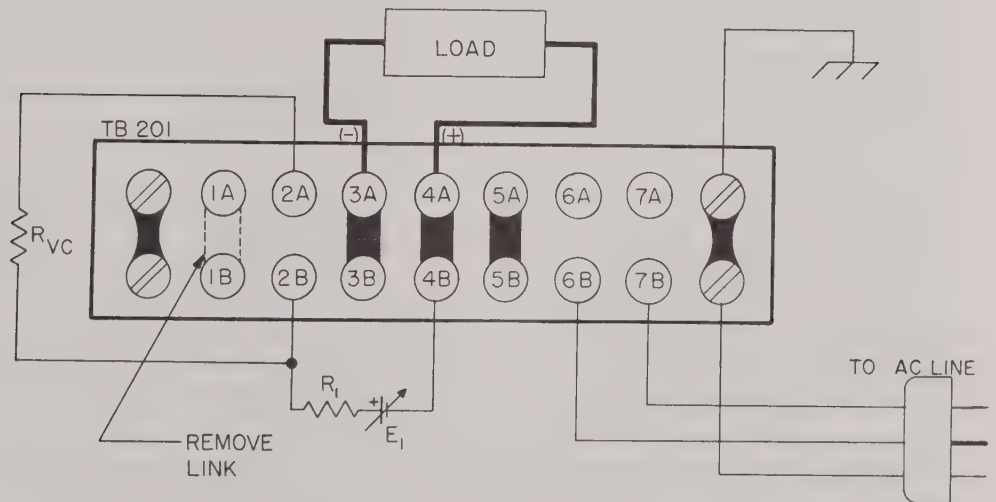


FIG. 3-5 CONNECTIONS FOR VOLTAGE PROGRAMMING

3-25 CONSTANT CURRENT OPERATION

- 3-26 The PAR power supply, normally a constant voltage supply, can be readily converted to supply constant current over a limited range. In the constant current operating mode, an external sensing resistor R_s and a current control R_{cc} are connected to the voltage comparison bridge externally, while the internal voltage control is disconnected. The voltage drop across R_s will now be regulated, thus providing constant current from the power supply. Characteristic of the constant current supply is its ability to change its output voltage automatically in order to maintain a constant current through a

range of possible load resistances. This output voltage which the supply delivers under constant current conditions is referred to as "Compliance Voltage". Since the PAR Power Supply automatically derates its output current with decreasing output voltage, the maximum constant current which can be drawn is a dependent function of the lower limit of the compliance voltage (See FIG. 3-3). At voltages below the locus of I_{limit} , current will automatically decrease.

3-27 The current sensing resistor R_S is chosen to develop a one volt drop (V_S) at the maximum desired current, (I_O). It is calculated by dividing this current into one volt, $R_S = \frac{V_S}{I_O}$. The value of R_S is not critical and can be the nearest standard resistance value available. Several facts should be kept in mind, however, when choosing R_S . A compromise must be made between a large and a small value. While a large value is desirable for good current regulation, it is less so in view of the power dissipated across it. It must be remembered that all the load current is flowing through R_S and the input to the regulator is connected to it. It is, therefore, vital that all extraneous changes across R_S , i.e., resistance change due to temperature, are kept to a minimum. A high quality, low T.C. (20 PPM) resistor, at least ten times the actual wattage needed, is therefore strongly recommended.

3-28 The current control resistor R_{CC} , is chosen on the basis of the control ratio of the Kepco Comparison Bridge, and V_S the maximum voltage across R_S . If R_S was selected for 1 volt drop, then $V_S = 1$ volt and

$$R_{CC} = V_S (\text{control ratio}), \text{ or } R_{CC} = 1 \text{ volt} \times \frac{1000 \text{ ohm}}{1 \text{ volt}} = 1000 \text{ ohms.}$$

A high quality, low T.C. (20 PPM) resistor is recommended for R_{CC} .

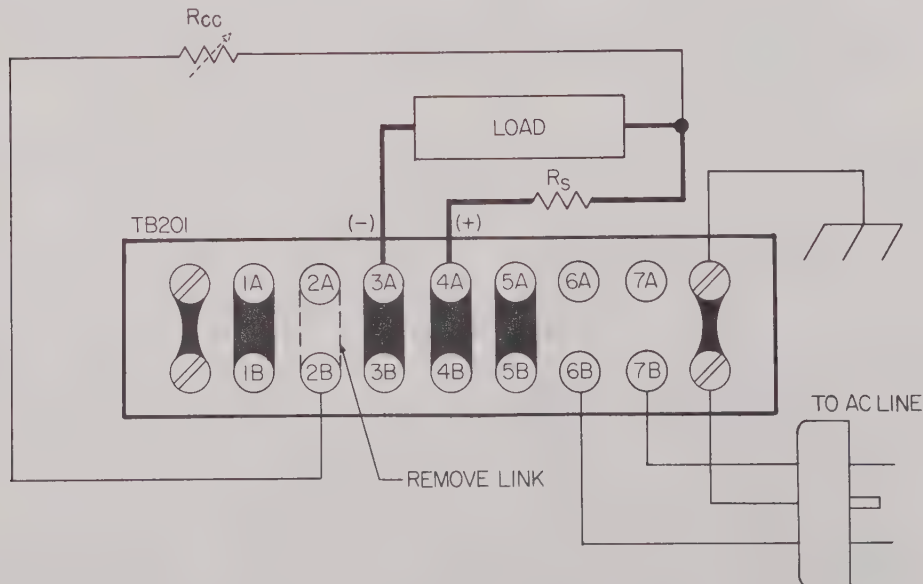


FIG. 3-6 CONNECTIONS FOR CONSTANT CURRENT OPERATION

3-29 PROCEDURE (Constant Output Current) (Refer to FIG. 3-6)

- 3-30 Connect programming components as shown in FIG. 3-6. The selection of these components will vary according to the individual application. Their calculation can be best shown by an example:

A PAR-48 is to be set up for constant current operation and must deliver 1 ampere (I_O) into a load whose effective resistance changes from 24 ohms to 48 ohms, (R_L). Consulting the derating graph, FIG. 3-3, we see that the compliance voltage limits are:

$$E_{\max} = I_O (R_L) = 1 \text{ A (48 ohms)} = 48 \text{ V}$$

$$E_{\min} = I_O (R_L) = 1 \text{ A (24 ohms)} = 24 \text{ V}$$

Since both limits are within the safe operating area (shaded portion of curve) operation under these conditions is permissible.

- a) Select R_S . Since we want 1 volt drop across it and $I_O = 1 \text{ A}$,
$$R_S = \frac{1 \text{ volt}}{1 \text{ A}} = 1.0 \text{ ohm};$$
 a wire-wound resistor, 1 ohm - 10 W with a T.C. of 20 PPM or better, will be adequate.
- b) The coupling resistor R_{CC} is found by:
$$R_{CC} = V_S \text{ times control ratio.}$$

$$R_{CC} = 1 \text{ volt (1000 ohm/V)} = 1000 \text{ ohm.}$$

3-31 REMOTE ERROR SENSING

- 3-32 Error sensing terminals (3b) and (4b) on the rear barrier-strip are the input to the supplies' regulating amplifier and are normally connected to the output terminals (3a) and (4a) by means of removable jumper links. Specified performance will therefore be provided at these points, with links in place. Since voltage drops across the load wires would degrade regulation directly at the load, the links connecting the sensing terminals to the output terminals can be removed and the sensing terminals can be connected directly at the load, thus compensating for the voltage drop across the load wires. Up to 0.5 volt drop in each load wire can be compensated for by using remote error sensing connections.

3-33 PROCEDURE (Refer to FIG. 3-7)

- a) Remove jumper links (3a)-(3b) and (4a)-(4b). Connect load as shown. Keep voltage drop in the load connecting wires as low as possible by using sufficiently heavy gauge leads.

- b) Using a twisted wire-pair, separate from the load connecting leads, connect terminal 3B to the negative, and terminal 4B to the positive connection at the load. The error sensing leads carry only the bridge current and may be approximately #20 gauge wire.

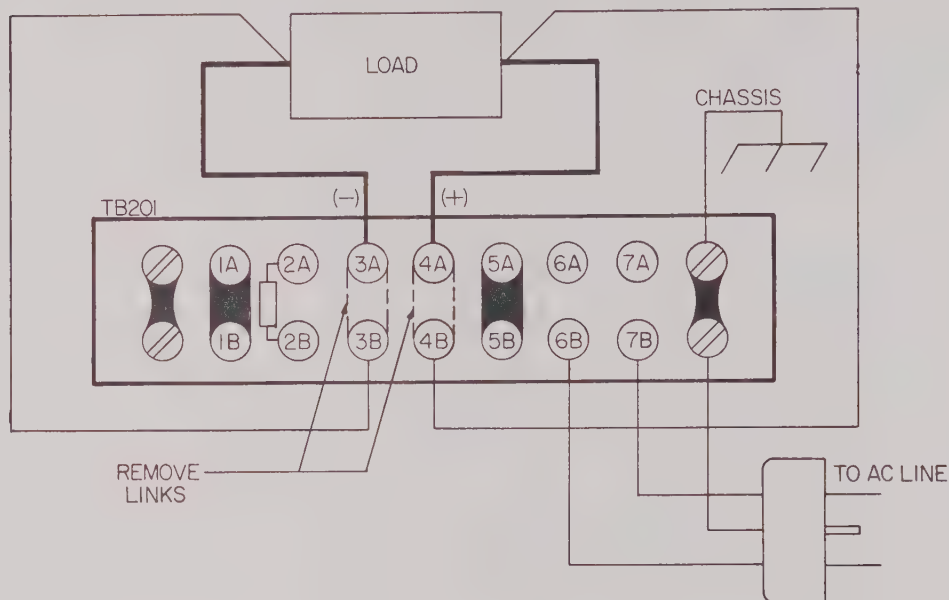


FIG. 3-7 CONNECTIONS FOR REMOTE ERROR SENSING

- CAUTION: 1) OPEN LOAD LEADS. Before power supply turn-on, make certain that the load wires are connected securely. Damage to the power supply circuitry will result from loose or disconnected load wires, since the power supply will attempt to maintain output current flow through the error sensing leads.
- 2) OPEN ERROR SENSING LEADS. Do not allow the power supply to operate with an open circuit or a loose connection between the sensing terminals and their respective load terminals. Although the output voltage-rise in such cases is limited (by protective diodes) to approximately 1.5 V, loss of the regulation and substantial increase in output ripple will result.
- 3) STABILITY AND TRANSIENT RESPONSE WITH REMOTE LOADS. Twisted loadwires of ample diameter and as short as possible are often helpful in reducing transient recovery time. Stability problems (oscillations), when working into loads with large reactive content, can often be resolved by connecting a capacitor directly at the remote load. In severe cases, lag network adjustment as described in paragraph 5-9 may be helpful.

3-34 SERIES OPERATION OF PAR POWER SUPPLIES

- 3-35 GENERAL. Kepco PAR power supplies can be series-connected for increase output voltage, provided, the specified limits on voltage to chassis are not exceeded. Series connected supplies must be protected by means of semiconductor diodes across the output terminals of each supply, as shown in FIG. 3-8. The peak inverse rating of these diodes must be at least as high as the output voltage of the supply to which they are connected. The continuous current rating of the diodes must be at least as large as the largest operating current of the supply to which they are connected.

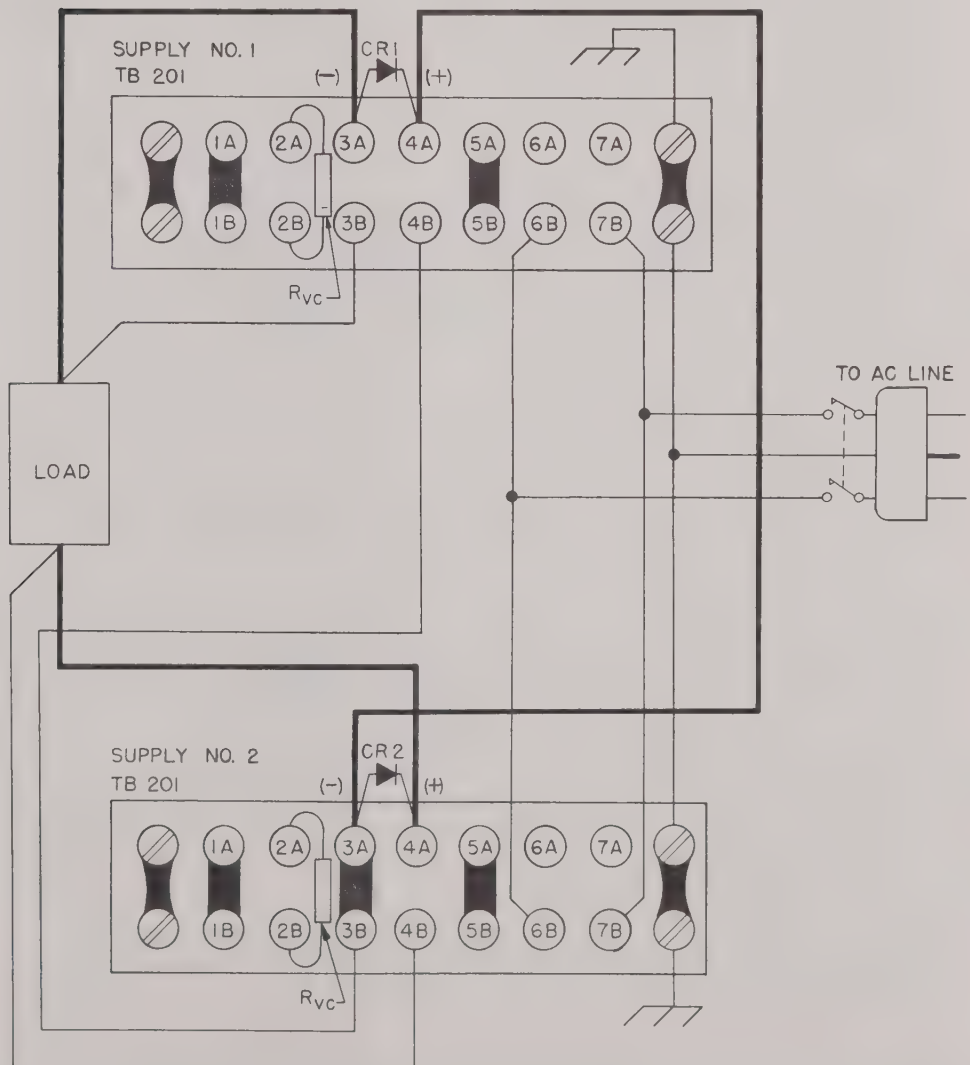


FIG. 3-8 CONNECTIONS FOR TWO PAR SUPPLIES IN SERIES

3-36 PROCEDURE (Refer to FIG. 3-8)

- a) Connect supplies and load as shown in FIG. 3-8. Keep voltage drop in load wires as low as possible by using heavy gauge wire.
- b) Connect protective diodes across the respective output terminals of the supplies.
- c) Remove jumpers as shown and connect error sensing leads to load. These leads carry only small currents and can be approximately #20 gauge wire.
- d) Apply line power simultaneously to both power supplies by using a common line switch (S1) as shown.

3-37 PARALLEL OPERATION

3-38 Up to three identical PAR power supplies may be paralleled for increased output current output in a master-slave connection. In this arrangement, the pass transistors and the associated circuitry are effectively in parallel and are driven from the master amplifier and driver.

3-39 PROCEDURE (Refer to FIG. 3-9)

- a) Connect supplies to the load with approximately equal lengths of wire having sufficient diameter to keep the voltage drop across it to a minimum.
- b) Open links (5A)-(5B) on slave units (1) and (2). Connect terminals (5B) on all three units with a shielded lead. Connect the shield to the ground terminal of the master unit.
- c) A common power line connection as shown in FIG. 3-9 is recommended for this operation. Remote error sensing if required may be used from the error sensing terminals of the master unit as described in Paragraph 3-27.
- d) Remove jumpers as shown and connect error sensing leads to load. These leads carry only small currents and can be approximately #20 gauge wire.
- e) Turn supplies "on" and adjust output on either one or both voltage controls as required.

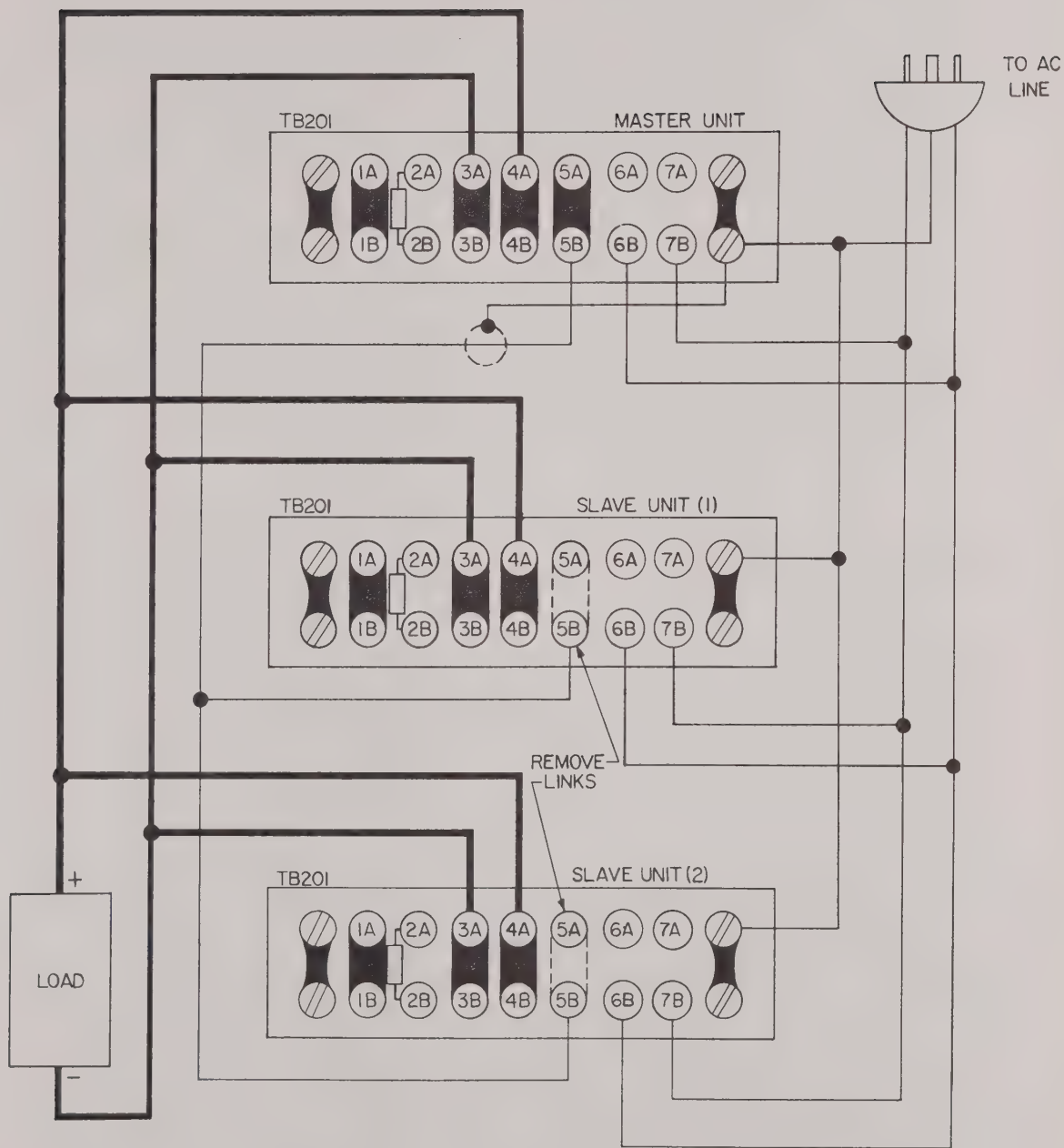


FIG. 3-9 PARALLEL OPERATION OF PAR SUPPLIES MASTER-SLAVE CONNECTIONS

SECTION IV - CIRCUIT DESCRIPTION

4-1 GENERAL (Refer to FIG. 4-1)

4-2 For the purpose of analysis, the KEPCO PAR Power Supply may be divided into six sections:

- a) The main DC power source.
- b) The pass-elements with driver and pre-driver amplifier.
- c) The comparison bridge.
- d) The error signal amplifier.
- e) The overload circuitry.
- f) The amplifier power supply.

Each of these sections will be discussed below. (Refer to FIG.'s 4-1, 4-2, 4-3, 4-4 and Main Schematic, FIG. 5-5).

4-3 Main DC Power Source. The main DC power is derived from a center-tapped winding on main transformer T201. Full-wave rectification and capacitive filtering are performed with silicon diodes CR301, CR302, and C202 respectively. The main power source delivers the output current and operating voltages for the series pass elements.

4-4 Pass Element Circuitry. (Refer to FIG. 4-3) The pass elements (or series control transistors) Q301 and Q302 are connected in series with the output terminals, so that the unregulated voltage (E_u) from the main power source is divided between them and the load. By changing the equivalent resistance of the series control elements, the voltage drop across them is made to change in such a way as to maintain a constant output voltage. The base drive current necessary for the pass elements to effect this change is supplied by the driver transistor Q303, which in turn is driven by the pre-driver and amplifier transistor Q2. Resistors R1, R10 and R15 are connected to sources of reverse bias, so that in the absence of a "turn-on" signal from the error signal amplifier, all driver and series control transistors will be held in the cutt-off condition.

4-5 Comparison Bridge Circuit. (Refer to FIG. 4-1) This four arm electrical bridge circuit is the regulating and controlling element in many KEPCO power supplies. In the PAR supply the four bridge arms consist of the reference voltage (E_r), derived from zener

diode CR7, reference resistors R25 and R26 (R_r), the voltage control resistor R201 (R_{vc}), and the output voltage E_o . The reference voltage E_r and the output voltage E_o are continuously compared to each other. In the balanced condition a constant bridge current I_b will flow through all four arms of the bridge, keeping the error voltage at terminals AA' at approximately zero volts. Any variation in the output voltage, or any change of value in any of the bridge components, will tend to change I_b and thereby produce an error signal across bridge terminal AA'. This error signal is then amplified and transferred to the series regulator transistors, changing the voltage drop across them in such a way to compensate for the variation.

4-6 Error Signal Amplifier. (Refer to FIG. 4-3) This high gain DC amplifier has the function of amplifying the error signal produced at the bridge terminals AA'. The null point of the bridge (A) is connected through R21 to the base of Q8 which, as an emitter follower drives Q7, connected in the common emitter mode. Q7 and Q8 therefore comprise the input stage of the amplifier. From the collector of Q7, the signal is transferred through R14 to the second voltage amplifier stage Q2, also operated in the common emitter mode. The emitter of Q2 is returned to a low impedance voltage source, the value of which sets the operating point of Q7. The collector of Q2 is directly connected to the base of Q3 which is operated as an emitter follower and functions as the pre-driver amplifier. Its emitter drives Q303, the main driver stage which finally in turn drives the bases of the series regulator transistors.

4-7 The Overload Circuitry. (Refer to FIG. 4-3) The PAR current limiting circuitry consists basically of the differential amplifier pair Q5 and Q6, inverting amplifier Q4 and a resistive network comprised by R3, R4* and R5. Current sensing resistor R4*, connected in series with the positive output lead, develops a voltage (V_s) proportional to the output current (I_o). A corresponding voltage is developed by the voltage divider consisting of R3 and R5 and is available at the movable tap on R5 (V_E). Both voltages are applied to the respective bases of Q5 and Q6. The action of the current limiting circuit depends on the relative magnitude of V_s and V_E . Since Q5 and Q6 are NPN transistors, the one with the more positive base voltage will conduct. Normally Q5 is biased off since V_E is set to a negative value (0.5V typical). Q5 can not conduct unless V_s (which opposes V_E) exceeds this value. As long as V_s is less in magnitude than V_E , Q6 will conduct, Q5 and consequently Q4 will cut off and the action of the regulator will not be affected.

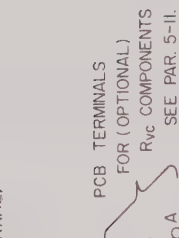
4-8 As the output current increases, V_s will increase and at some point it will exceed V_E . Q5 will conduct and drive Q4 into conduction. Q4 will tend to cut-off Q2 which will in turn cut-off the drivers and through them the pass elements. As a result the output voltage E_o begins to fall. This brings with it a reduction of V_E and consequently V_s , as

*R204 in models PAR-4 and PAR-7

the output current I_O is decreasing simultaneously. The overload circuitry will attempt to establish an equilibrium condition between V_S and V_E . Therefore as the output voltage E_O continues to decrease, the output current will decrease linearly with E_O until at the limiting value of R_L (zero, i.e. short circuit) E_O is zero volts and I_O less than 10% of its maximum rated value. At short circuit therefore, an unusual degree of protection is afforded to the load as well as to the power supply itself.

- 4-9 The Amplifier Power Supply. (Refer to FIG. 4-4) This auxiliary supply delivers all necessary operating voltages for the DC amplifier and supplies the reference voltage. It is derived from a winding on regulator transformer T201. Silicon diodes CR1 and CR2 comprise a full wave rectifier, with C1 as the capacitor input filter. A constant current source (Q1), followed by two zener diodes (CR4, CR5) provides the operating voltages for the amplifier. The reference voltage for the comparison bridge circuit is derived from zener diode CR7.

NOTE:



PAR/18-67

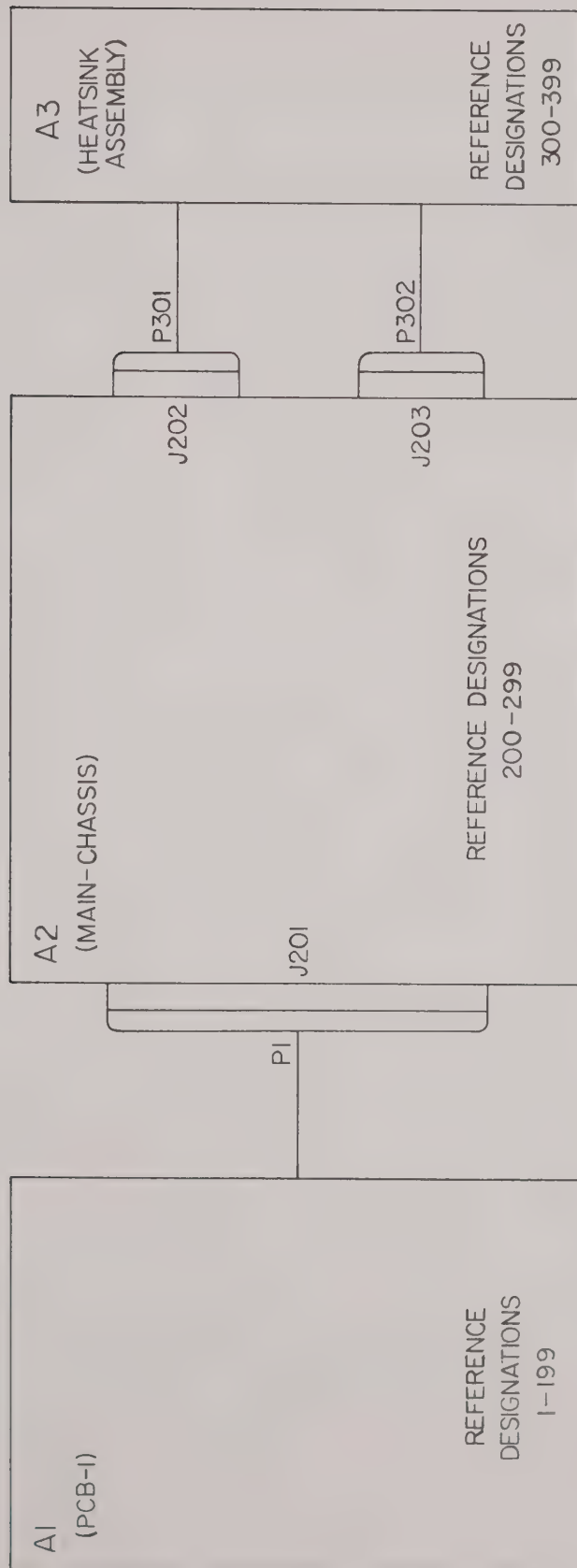


FIG. 4-2 CONNECTING DIAGRAM, PAR POWER SUPPLY

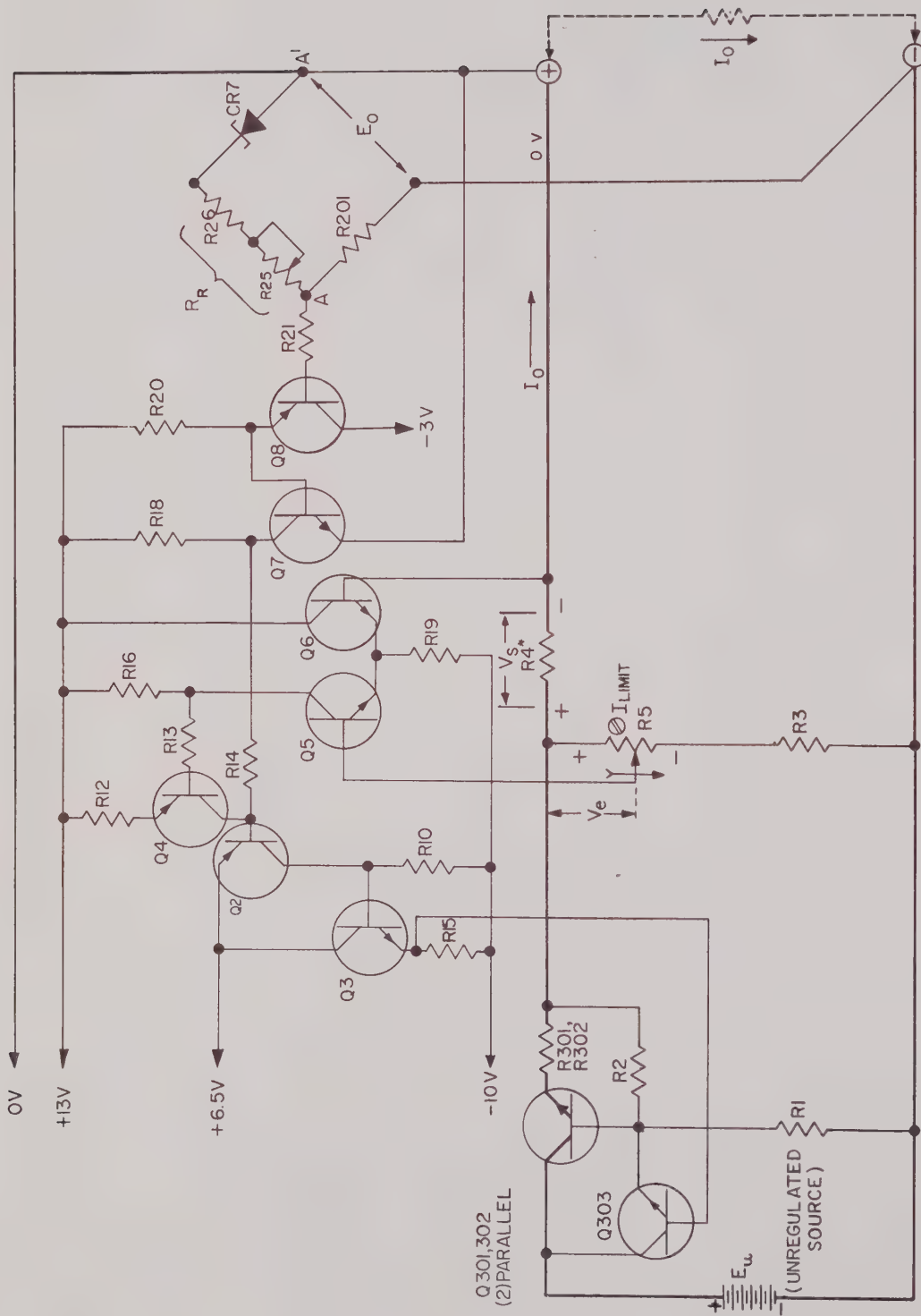


FIG. 4-3 PAR AMPLIFIER DETAIL

*Note: R4 is R204 on PAR 4 and PAR 7

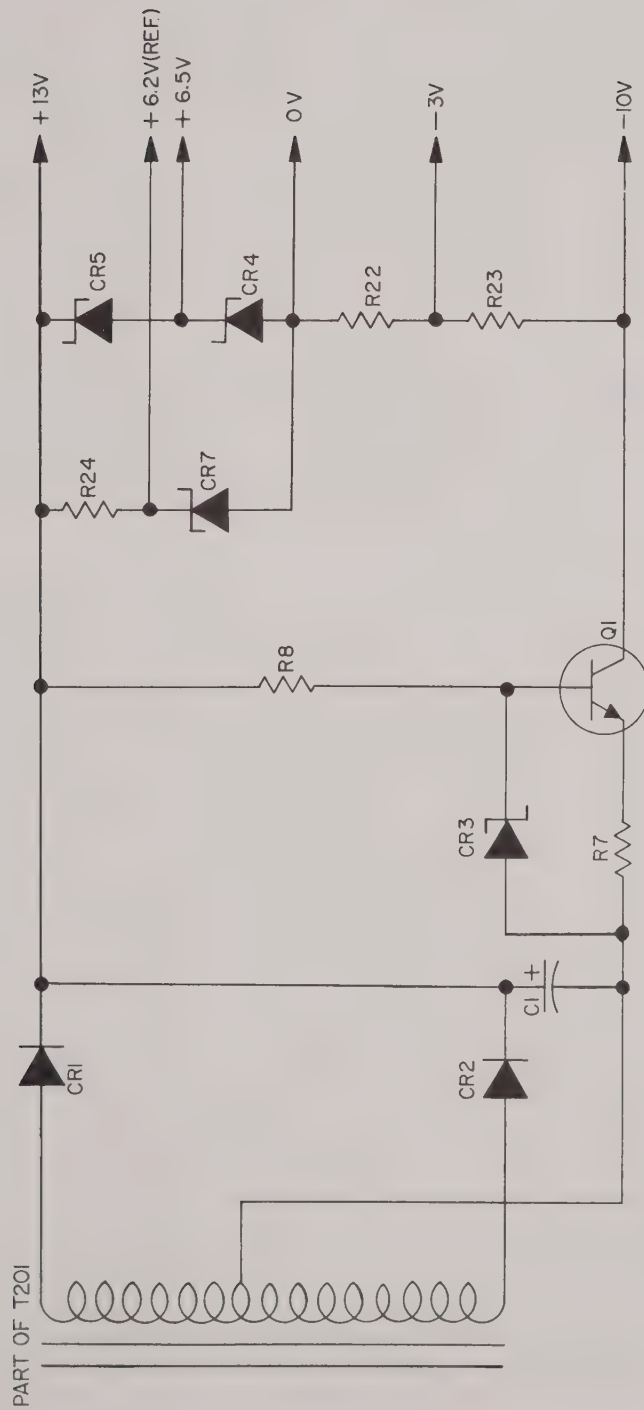


FIG. 4-4 PAR - AMPLIFIER POWER SUPPLY, DETAIL

SECTION V - MAINTENANCE

5-1 GENERAL

5-2 Conservative rating of all components and the avoidance of congested lay-out in the KEPCO PAR Power Supply should keep maintenance problems to a minimum. If component failure should take place however, the ease of disassembling the unit will keep "down time" of the equipment to a minimum.

5-3 DISASSEMBLY

5-4 (Refer to FIG. 5-3) Most components on the PAR power supply are mounted on two plug-in type assemblies, which can be removed readily after loosening the two holding screws securing them to the main chassis. All other components are mounted on the main chassis and are easily accessible.

5-5 INTERNAL ADJUSTMENT PROCEDURES

5-6 Current Limiting Control (I_{limit}). A single turn potentiometer (R5), located on the printed circuit board and facing the barrier strip (FIG. 5-4) serves as an adjustment for limiting the output current through the range of approximately 5% to 100% of the supplies' maximum output current.* R5 is factory adjusted to limit at approximately 105% of the maximum output current.* Normally, readjustment of the current limit is not required, since at reduced output voltages current limiting takes place automatically. (Refer to FIG. 3-3)

5-7 If another than the preset limit is desired however, it can be conveniently adjusted as follows:

- a) Set up supply to draw the desired output current and monitor the output with an oscilloscope having a vertical sensitivity of at least 1 mV/cm.
- b) Turn current limit adjustment R5 slowly counter clockwise until output ripple increases substantially. Back off until output ripple appears normal again.
- c) Short circuit supply by connecting a DC ampere meter across its terminals. The short circuit current will be approximately 5% of the maximum rated output current.

*The "maximum rated output current" of the power supplies in the PAR Design Group is a function of ambient operating temperature. Refer to Paragraph 3-1.

CAUTION: When resetting the current limit for the full maximum output current of the unit, do not simply turn the limit control fully clockwise, but proceed as described below. Due to tolerances built-ups, the extreme clockwise position of the limiting adjustment may produce a considerable increase in dissipation across the pass elements and their consequent destruction.

5-8 When resetting to the full output current is required, connect supply as previously shown in Paragraph 5-7.

- a) Set Output Voltage to 95% of its maximum rated output voltage.
- b) Slowly increase the output current by reducing the load resistance.
- c) Turn current limit R5 slowly clockwise and monitor the output current as well as the ripple. Proceed until the maximum current of the unit can just be drawn while the output ripple is still normal.

5-9 LAG NETWORK ADJUSTMENTS. The two adjustable lag networks provided in the PAR power supply are factory adjusted for maximum stability of the error signal amplifier when working into resistor loads. Re-adjustments are necessary only after component replacement, for operation into remote loads, or loads with large reactive components, where instability (oscillation) is encountered. Adjustment consists of turning R11 and R17 (Lag I and II respectively, refer to FIG. 5-4 for location) until oscillations disappear and maximum stability is re-established.

5-10 INSTALLATION AND ADJUSTMENT OF OPTIONAL VOLTAGE CONTROL

5-11 If the PAR power supply is used as a fixed voltage source, the voltage control resistance R_{VC} , normally connected in the factory to barrier strip terminals 2A and 2B, may be installed internally on the printed circuit board as shown schematically in FIG. 4-1 and physically in FIG. 5-4. Several configurations of R_{VC} are possible.

- a) R_{VC} may be the fixed resistor delivered with the unit and normally connected to barrier strip terminals (2A) and (2B). It can be placed between points (C) and (D), (see FIG. 5-4) by first removing the wire jumper normally installed between these points, and jumping barrier terminals (2A) and (2B) with a short length of wire.
- b) R_{VC} may be made up entirely as a variable resistor by mounting it as indicated in FIG. 5-4, removing the wire jumper between points (A) and (B), and soldering the centertap and one end of the variable resistor to points (A) and (B). Jump barrier terminals (2A) and (2B) with a short length of wire.

- c) A combination of fixed and variable resistors can be used to serve as voltage control with partial adjustment. The variable resistor is wired between points (A) and (B), and installed as before. The fixed resistor must be mounted between points (C) and (D). The two barrier terminals (2A) and (2B) must be jumped with a short length of wire, as before.
- d) Any combination of high quality resistors may be chosen, as long as their temperature coefficient is lower than 100 ppm. After installation of the desired components, the power supply is adjusted to the chosen output voltage by varying the newly installed control, or if a fixed resistor has been installed, by varying the original "E₀ max." or fine control.

5-12 TROUBLE SHOOTING

- 5-13 The use of high quality components in this Power Supply should assure long trouble-free operation if the instrument is used within its specifications. If a component should fail however, disassembly of the unit and part replacement are made convenient by the printed circuit board construction and sound mechanical engineering.
- 5-14 Servicing beyond simple part replacements should be attempted only by personnel thoroughly familiar with solid state components and with experience in closed loop circuitry. Since "trouble-shooting charts" containing resistance and voltage measurements at various places in the equipment are not very useful in feedback amplifiers, we have not included them in this manual. Presented instead is a fairly extensive circuit description (Section IV), detailed diagrams showing adjustment and parts location (See FIG. 5-3, 5-4) as well as the Main Schematic, which together should provide the necessary information for qualified personnel in the repair of this instrument. Kepco Field Engineers and the Kepco Repair Department are always available for prompt service in difficult cases.

5-15 POWER SUPPLY MEASUREMENTS

- 5-16 Measurement of the significant parameters of a power supply is a requirement for incoming inspection, periodic maintenance, or after component replacement. Since these measurements require special techniques to insure correct results, suggestions for their performance are given below: (See FIG.'s 5-1, 5-2)

a) Required Instrumentation:

- 1) Constant AC Supply voltage with provisions for "stepping" the voltage over a specified region (105 to 125 V AC or 210 to 250 V AC); a variable auto-transformer is generally adequate, if it is rated to deliver the input current of the unit under test.
- 2) Resistive load, variable, with on and off switch and capable of dissipating the full output power of the unit under test.
- 3) DC Voltage Monitor, differential voltmeter, or power supply analyzer which displays the percentage regulation directly.
- 4) Current measuring resistor, (R_m) for current regulation measurements, four terminal device.
- 5) AC Ripple monitor, sensitivity better than 1 mV, Ballantine Model 302C, or H.P. Model 400H.
- 6) Optional: Oscilloscope, vertical sensitivity better than 1 mV/cm.

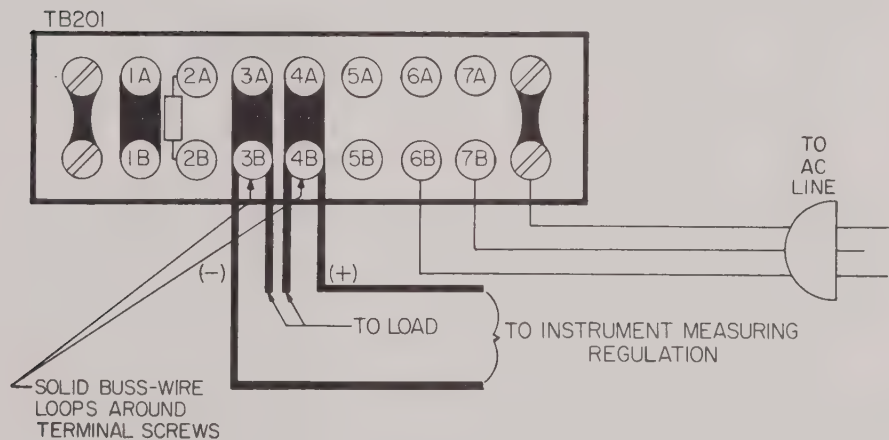
b) The Four Terminal Network is an essential device for precise measurement of regulation. It can be approximated by the method shown in FIG. 5-1. FIG. 5-2 shows the proper location of instrument leads when measuring regulation. The principle governing this method of measurement is simply not to measure any voltage drops due to load current flow. This can only be avoided by measuring regulation either directly at the sensing leads or by the use of the four-terminal network.

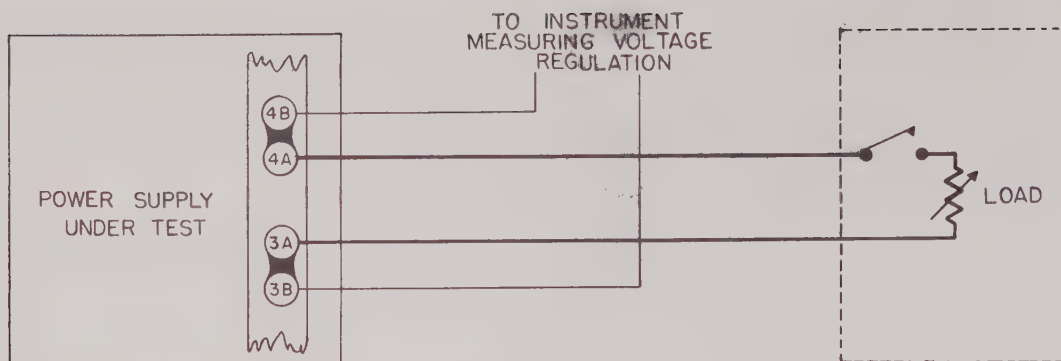
c) Voltage Regulation is defined as the amount of output voltage change resulting from a specified change of line voltage or from a change in load resistance. It can be expressed as an absolute change ΔV or as a percentage in reference to the total output voltage E_O :

$$\% \text{ Voltage Regulation} = \frac{\Delta E_O}{E_O} \times 100\%.$$

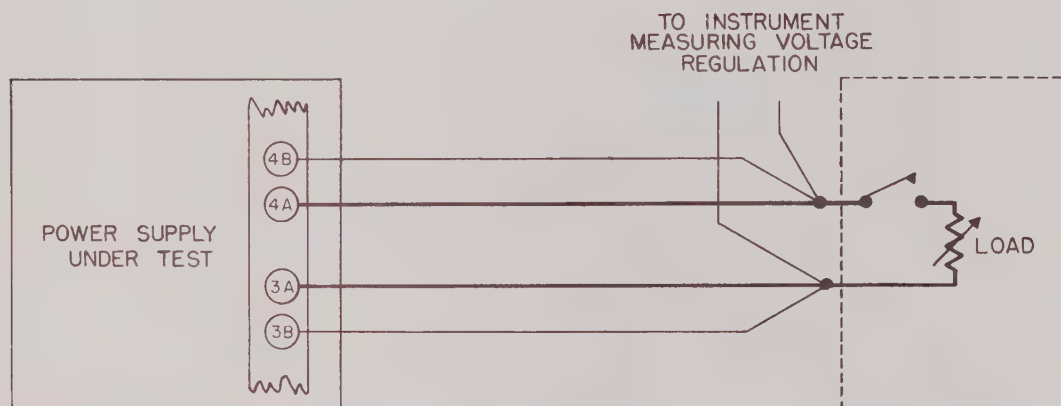
d) Ripple. An oscilloscope of suitable sensitivity, or a true rms reading meter may be used to monitor and measure the ripple voltage of the power supply either across the output terminals (Voltage regulation mode) or across the current measuring resistor (R_m) when measuring ripple in the external current regulation mode. If an oscilloscope is used only, the peak to peak/rms ratio, which for a pure sine wave is close to 2.83:1, may be approximated for the broken wave form of a series regulated power supply as 3:1.

Since ripple specifications in the external current regulation mode are given in milliamperes, the rms voltage readings across R_m must be divided by the value of R_m .

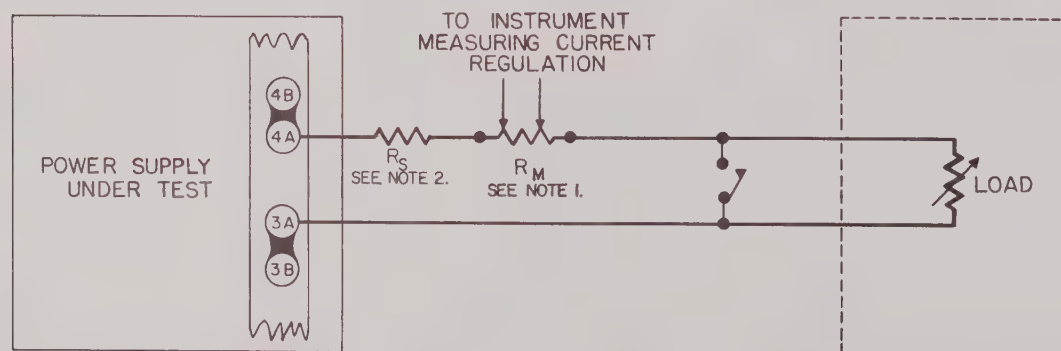




A) REGULATION MEASUREMENT (VOLTAGE)
WITHOUT ERROR SENSING AT THE LOAD



B) REGULATION MEASUREMENT (VOLTAGE)
WITH ERROR SENSING AT THE LOAD



C) REGULATION MEASUREMENT (CURRENT)

NOTES: 1. R_M SHOULD BE A FOUR TERMINAL NETWORK CONFIGURATION AND MUST BE SELECTED SUCH THAT ITS WATTAGE RATING IS AT LEAST 10 TIMES THE ACTUAL POWER DISSIPATED. STABILITY AND REGULATION OF THE POWER SUPPLY DEPEND ON THE STABILITY OF R_M . RECOMMENDED T.C. FOR R_M IS 20 P.P.M.
2. REFER TO MANUAL SECTION III FOR SELECTION OF R_S .

FIG. 5-2 POWER SUPPLY MEASUREMENTS, CONNECTING METHODS

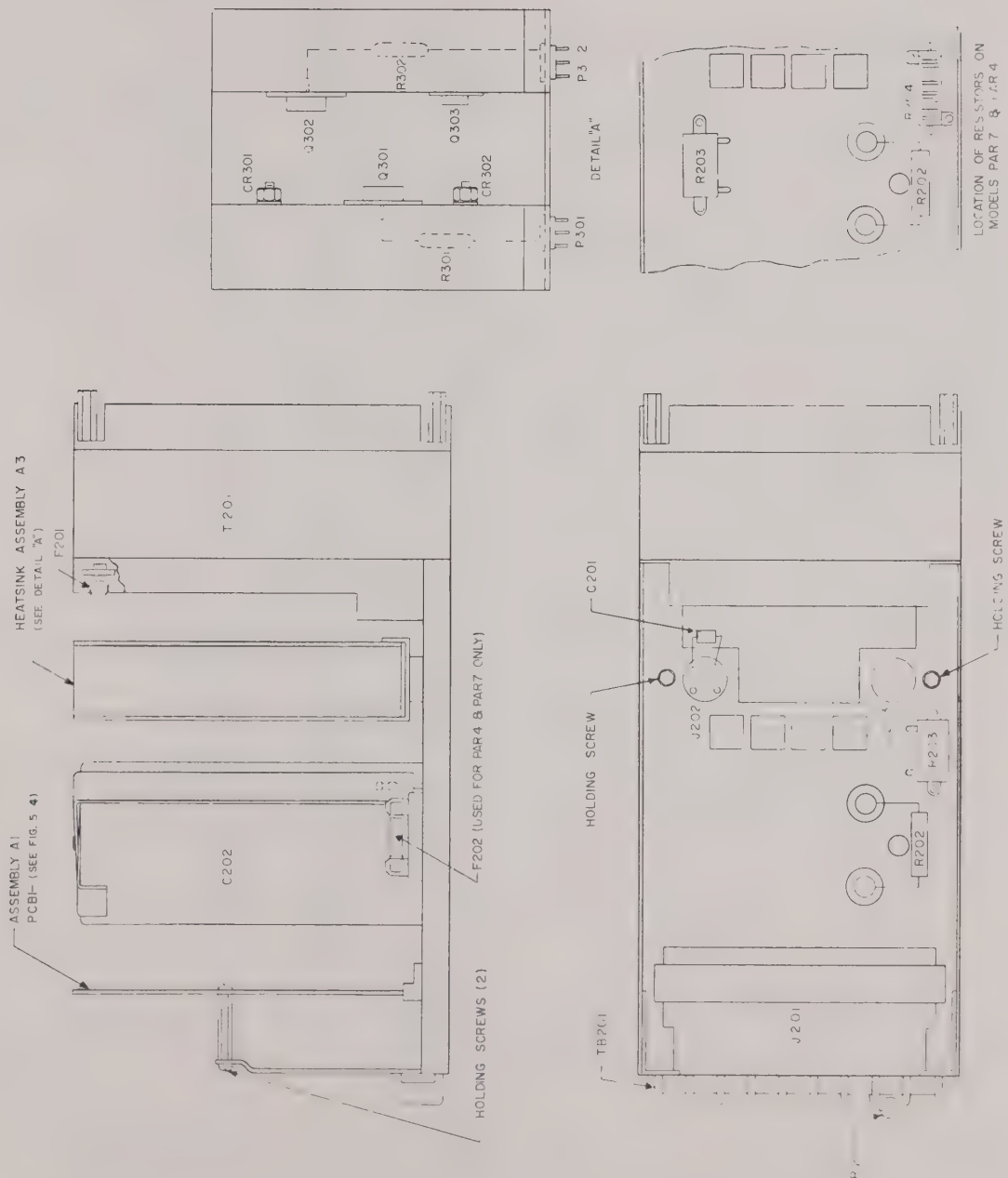


FIG. 5-3 COMPONENT LOCATION, MAIN CHASSIS, ASSEMBLY A2
AND HEATSINK, ASSEMBLY A3

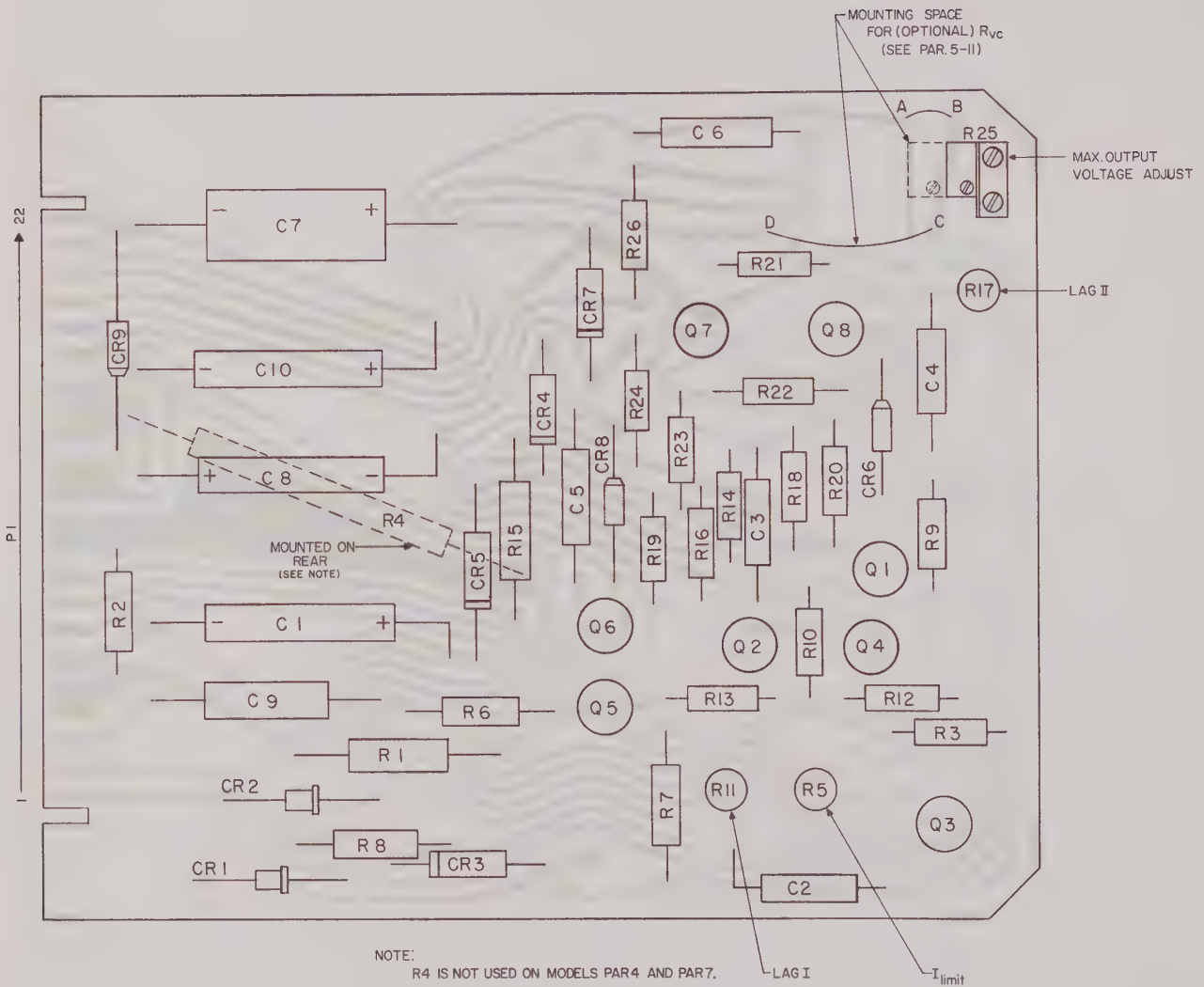


FIG. 5-4 COMPONENT LOCATION, PCB-1, ASSEMBLY A1



- REAR BARRIER-STRIP TB201

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5-9/5-10



REPLACEMENT PARTS LIST

MODEL PAR 4 (C), AMPLIFIER PCB#1, ASSEMBLY A1 Code 3-1367

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
C1	1	Capacitor, Electrolytic, Pigtail 68 μ F, 50 V, 20%	General Electric 76F02LN680	117-0511
C2	1	Capacitor, Mylar, Pigtail 0.05 μ F, 200 V, 20%	Sprague 192P503025	117-0315
C3,5	2	Capacitor, Mylar, Pigtail 0.01 μ F, 200 V, 10%	Sprague 192P10302	117-0353
C4	1	Capacitor, Mylar, Pigtail 0.02 μ F, 200 V, 10%	Sprague 192P30392	117-0377
C6	1	Capacitor, Mylar, Pigtail 0.2 μ F, 200 V, 10%	TRW X663F	117-0236
C7	1	Capacitor, Electrolytic, Pigtail 1.5 K μ F, 10 V	General Electric 43F7282A	117-0417
C8,10	2	Capacitor, Electrolytic, Pigtail 560 μ F, 3 V, 20%	General Electric 76F02BN561	117-0529
C9	1	Capacitor, Mylar, Pigtail 0.1 μ F, 600 V, 20%	Wesco Type 33MM	117-0316
CR1,2	2	Rectifier, Silicon, Pigtail	Semicon SM110	124-0133
CR3,4,5	3	Zener Diode	Transitron SV125	121-0028
CR6,8,9	3	Rectifier, Silicon, Pigtail	Solitron HVP	124-0178
CR7	1	Zener Diode	IRC 1N821	121-0041
Q1	1	Transistor, Silicon, NPN	RCA 2N3053	119-0059
Q2	1	Transistor, PNP	Fairchild 119-0076	119-0076
Q3,5,6,7	4	Transistor, NPN	General Electric 2N336A	119-0056
Q4,8	2	Transistor, Silicon, PNP	Hughes 2N1131A	119-0055
R1	1	Resistor, Fixed, Molded 510 ohm, 1/2 W, 5%	Allen Bradley EB5115	115-0824
R2	1	Resistor, Fixed, Molded 68 ohm, 1/2 W, 5%	Allen Bradley EB6805	115-0904
R3,13	2	Resistor, Fixed, Molded 2.2 K ohm, 1/2 W, 10%	Allen Bradley EB2221	115-0466
R5	1	Resistor, Variable, Cermet 500 ohm, 0.5 W, 10%	Helipot 62PR500	115-2043
R6	1	Resistor, Fixed, Molded 10 ohm, 1/2 W, 10%	Allen Bradley EB1001	115-0502

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

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REPLACEMENT PARTS LIST

MODEL PAR 4(C), AMPLIFIER PCB#1, ASSEMBLY A1

Code 3-1367

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
R7	1	Resistor, Fixed, Precision, M.F. 232 ohm, 1 W, 1%	IRC CES M-Coat	115-1953
R8	1	Resistor, Fixed, Molded 3.3 K ohm, 1 W, 10%	Allen Bradley GB3321	115-0678
R9	1	Resistor, Fixed, Molded 3.3 K ohm, 1/2 W, 10%	Allen Bradley EB3321	115-0439
R10	1	Resistor, Fixed, Molded 20 K ohm, 1/2 W, 10%	Allen Bradley EB2035	115-0555
R11, 17	2	Resistor, Variable, Cermet 200 ohm, 1/4 W, 30%	Helipot 62PR200	115-2072
R12, 21	2	Resistor, Fixed, Molded 100 ohm, 1/2 W, 10%	Allen Bradley EB1011	115-0626
R14	1	Resistor, Fixed, Molded 2.7 K ohm, 1/2 W, 10%	Allen Bradley EB2721	115-0560
R15	1	Resistor, Fixed, Molded 12 K ohm, 1/2 W, 10%	Allen Bradley EB1231	115-1168
R16	1	Resistor, Fixed, Molded 1.2 K ohm, 1/2 W, 10%	Allen Bradley EB1221	115-1129
R18	1	Resistor, Fixed, Precision, M.F. 6.81 K ohm, 1 W, 1%	IRC Type CES	115-1802
R19	1	Resistor, Fixed, Molded 10 K ohm, 1/2 W, 10%	Allen Bradley EB1031	115-0489
R20	1	Resistor, Fixed, Precision, M.F. 24,300 ohm, 1 W, 1%	IRC Type CES	115-1806
R22	1	Resistor, Fixed, Molded 130 ohm, 1/2 W, 10%	Allen Bradley EB1315	115-1859
R23	1	Resistor, Fixed, Molded 300 ohm, 1/2 W, 10%	Allen Bradley EB3015	115-0783
R24	1	Resistor, Fixed, Precision, M.F. 750 ohm, 1 W, 1%	IRC CES M-Coat	115-1803
R25	1	Resistor, Variable, Multiturn 3 K ohm, 1/2 W, 10%	Bourns 3067P-1-302	115-1668
R26	1	Resistor, Fixed, Power, Axial 5 K ohm, 3 W, 5%	Hardwick Hindle 9/16 GA-5000 LTC	115-1094

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REPLACEMENT PARTS LIST

MODEL PAR 4(C), MAIN CHASSIS, ASSEMBLY A2

Code 3-1367

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
C201	1	Capacitor, Mylar, Can 0.1 μ F, 200 V, 20%	Sprague 192P10402	117-0186
C202	1	Capacitor, Electrolytic, Can 90 K μ F, 15 V	General Electric 43F3710CA6	117-0450
F201	1	Fuse, Instantaneous 5 A	Bussman AGC-5	141-0033
F202	1	Fuse 12 A	Little Fuse 314012	141-0067
R201	1	Resistor, Fixed, Precision, M.F. 4.02 K ohm, 1 W, 1%	IRC CES M-Coat	115-1902
R202	1	Resistor, Fixed, Power, Axial 100 ohm, 5 W, 5%	Tepro TS-5W	115-0400
R203	1	Resistor, Fixed, Power, Axial 20 ohm, 10 W, 5%	Hardwick Hindle 3/4 BRS-53B	115-1907
R204	1	Resistor, Fixed, WW 0.045 ohm, 25 W, 5%	Tepro TM-25	115-1904
T201	1	Transformer	Kepco Magnetics	100-1686

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REPLACEMENT PARTS LIST

MODEL PAR 4(C), HEATSINK ASSEMBLY, A3

Code 3-1367

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
CR301,302	2	Rectifier,Silicon,Stud Type	Tung Sol 1N3210	124-0165
Q301,302	2	Transistor,Silicon,NPN	RCA 2N3772	119-0075
Q303	1	Transistor,Silicon,NPN	RCA 40250	119-0068
R301,302	2	Resistor,Fixed,Power,Axial 0.05 ohm, 5 W, 5%	Tepro TS5W	115-1523

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